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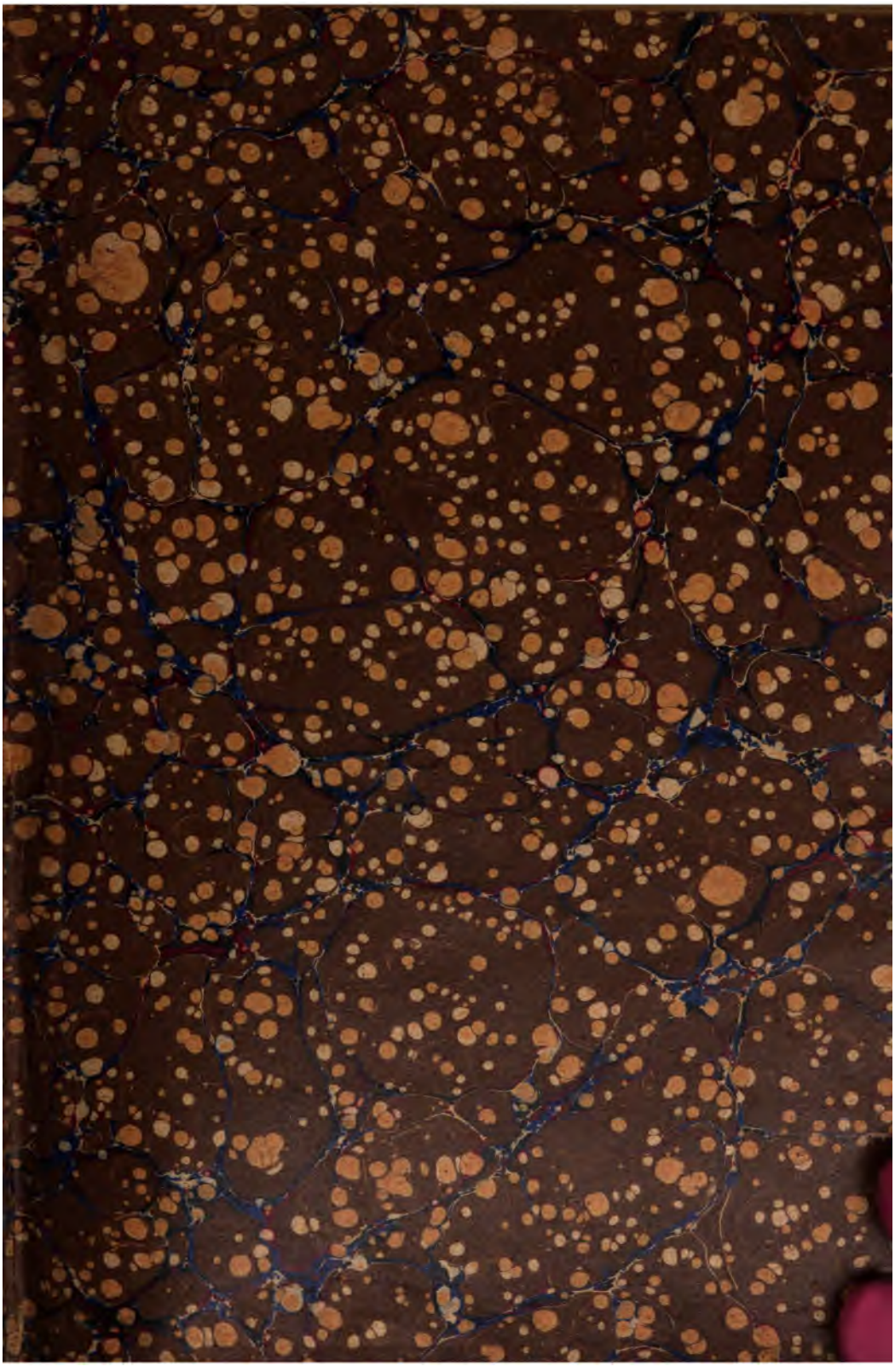

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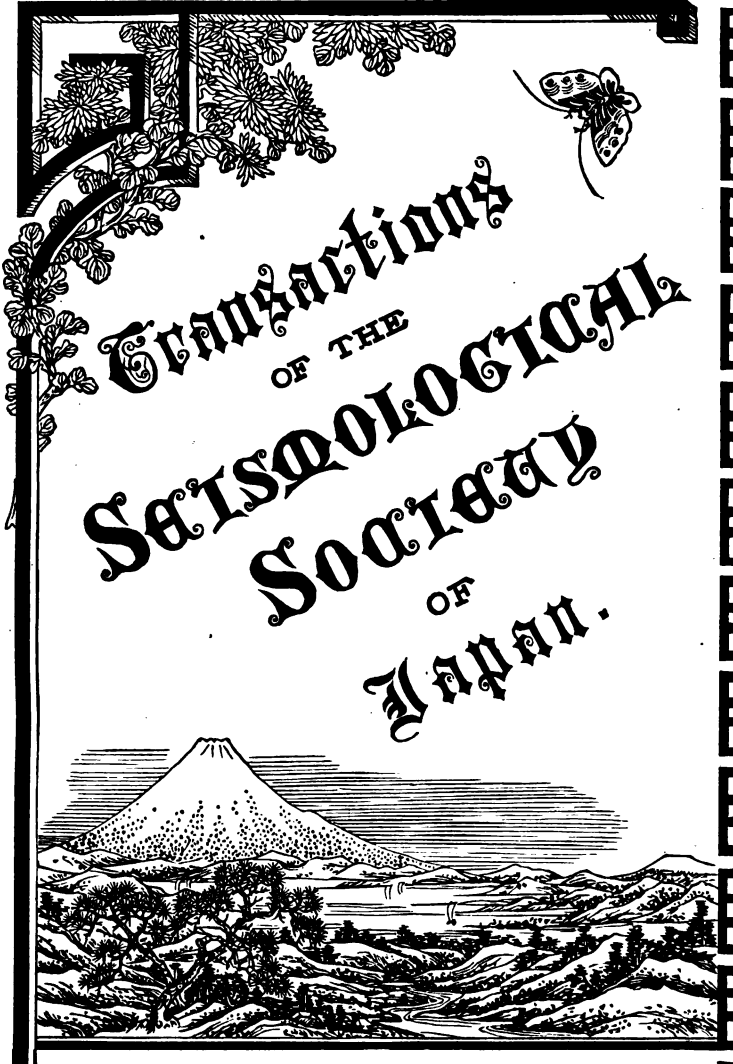

Transactions of the Seismological Society of Japan.

Vol. X.

PRINTED AT THE OFFICE OF THE "JAPAN MAIL,"
YOKOHAMA.

TRANSACTIONS

OF THE

SEISMOLOGICAL SOCIETY

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213189

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ON A SEISMIC SURVEY MADE IN TOKIO IN 1884 AND 1885.

BY JOHN MILNE,

IMPERIAL COLLEGE OF ENGINEERING.

[READ JANUARY 27TH, 1886.]

1. INTRODUCTION.—Description of ground on which the Survey was made. The Instruments, Methods of Observation, Calculations, &c.

2. RECORDS.—A detailed description of Diagrams with deductions for Special Earthquakes.

3. CONCLUSIONS.

I.—INTRODUCTION.

The following paper is an account of a series of observations made upon earthquakes felt in Tōkyō between March, 1884, and March, 1885. The place of observation was the grounds of the Imperial College of Engineering. These grounds are situated at a slightly higher elevation than the alluvial plain on which a great portion of Tōkyō is built; at the same time they are near to the foot of several of the bluffs which form the edges of the plateau which overlooks the city. Speaking generally, the ground is flat. On its western side it is somewhat marshy, but the remainder of the ground is dry and hard. From the detailed plan of the ground, which was specially surveyed and drawn under the superintendence of my colleague Mr. T. Alexander to illustrate this paper, all details respecting topography, the position of buildings, moats, observing stations, &c., may be readily seen.

On the higher parts of the ground you may sink at least ten feet without meeting with water. From a bore hole half way between stations F and C a vertical section is approximately as follows :—

	feet.
Earth and sand	78
Very hard gravel	2.5
Fine gravel	2.
Sand	6.5
Gravel	10.5
Tuff, a soft volcanic clay rock	—

This last material is probably the commencement or very near the commencement of the stratified tuff formation which,

at Yokohama and other places in and near to Tōkyō, is exposed in cliff-like sections.

On the marshy ground, water is met with at a depth of two or three feet.

The area of the ground on which the observing stations are situated is about nine acres.

The general result of the observations has been to show that the amount and character of movement in different parts of the ground has invariably been very different. The instruments employed were bracket seismographs. These wrote the motion of the ground as two components, one being N. and S. and the other E. and W. The pointers giving these records were arranged to write side by side on the surface of a long smoked glass plate. This plate was carried on a light carriage, which at the time of an earthquake was drawn along horizontally beneath the pointers in a direction parallel to their length. All the seismographs were attached to a strong wooden stands strengthened with angle iron. This was fixed on the head of a stake, level with the surface of the ground. The depth to which the stake was driven was in all cases about 2 feet 6 inches. At the time of an earthquake the carriages at all the stations were released simultaneously by a current from 33 Daniel cells. At the time of an earthquake, a contact maker at my house closed the circuit of 2 Leclanché cells, which by means of an electro magnet released a small pendulum which was usually held deflected. At each swing of this pendulum it passed through a small cup of mercury. The first contact with the mercury brought the large battery of Daniel cells into action. At every succeeding swing of this pendulum a current was sent to each of the stations, where by means of electro magnets small levers were deflected. The successive deflections of these levers caused marks corresponding to the swings of the pendulum to be made along the edges of the moving plates. Thirty swings or sixty contacts were made in 22 seconds. Therefore the intervals between the marks on the

plate represented .366 seconds of time. By this means it became an easy matter to compare the motion between any of the stations to within $\frac{1}{100}$ sec. of time. For a description of the seismograph and the contact maker see Systematic Observation of Earthquakes, Trans. Seis. Soc., Vol. IV., p. 87-117.)

For the loan of the greater portion of the telegraph wire and posts I am indebted to the kindness of Mr. T. Ishi, Director of the Imperial Telegraphs. For the remainder of the wire, and its erection, I am indebted to Mr. Takeda, Director of the Imperial College of Engineering.

All the instruments were installed so that the plates ran from north to south. In addition to observations made on the surface of the ground, several earthquakes were recorded at the bottom of a pit 10 feet deep, and several inside a house which, at its foundations, rested on cast iron shot. The object of the experiments with the house was to determine a form of foundation to avoid the acquisition of momentum.

This building measures 20 feet by 14 feet. It is constructed of timber with a shingle roof, plaster walls, and a ceiling of laths and paper. The first balls which were used were 10 inches in diameter. They rested on cast iron plates with saucer-like edges fixed on the head of piles. Above the balls, and attached to the building, were cast iron plates *slightly* concave but otherwise similar to those below. The result of this arrangement, which was very similar to an arrangement employed by Mr. David Stevenson for the lamp tables in some of the Japanese lighthouses, was to reduce the *sudden* shock-like movement of an earthquake to a *slow* back and forth motion. Although these foundations greatly eliminated the destructive part of an earthquake disturbance, there was so much motion due to the effects of wind and other causes that they were abandoned. Next I employed 8 inch balls, and after that 1 inch shot. Now the building rests at each of its piers upon a handful of cast iron shot about

¼ inch in diameter. These are between flat cast-iron plates. By this means the rolling friction has been so far increased that the house is astatic and at the same time uninfluenced by ordinary gales of wind. At the time of an earthquake the motion is extremely small, as will be seen by reference to the diagrams.

A few of the latter observations were made at the bottom of a pit 10 feet in depth. At the bottom of this pit the ground is hard and dry. The instrument in this pit was installed similarly to the instruments on the surface.

All the diagrams are tracings taken from photographs of the actual records on the glass plates. The errors in them are due to shrinkage or extension of the paper during the process of taking photographs and slight irregularities due to carelessness in the process of tracing, preparatory to transfer to the lithographer's stone. The shortness of the plates on which the movements were written prevented the whole of the earthquake being recorded. A farther reduction in the length of the diagram has been made by the lithographer. Although in some cases the diagrams may not represent more than the third of an earthquake, there is still quite sufficient given to determine the character of the disturbance.

It may here be remarked that the whole of an earthquake has never yet been recorded. Many of the preliminary tremors have been lost on account of a want of sufficient multiplication in the instrument, whilst concluding vibrations have been lost on account of the frictional resistances of the instrument preventing it recording the slow pulsatory movements which often bring an earthquake disturbance to a close.

Another point to be remarked is that the earthquakes here recorded by no means represent the whole of the earthquakes which occurred during the period of observation. Had I been provided with assistants to smoke plates, photograph, repair instruments and telegraph lines after storms, to make daily visits to the different stations and see that the instruments were

in working order, &c., it is possible that double the number of earthquakes which I have recorded might have been successfully captured. Where records are only given for one or two stations it must be assumed that the instruments at the other stations were for various reasons not working. On May 29th, 1884, the instrument at C was moved to D. On December 30th, F and E were started, and the instrument at B was exchanged with that at D. On February 15th, 1885, the instrument at G was started, F was discontinued and moved to J, when it was placed side by side with a similar instrument.

The more important elements which I have recorded for different earthquakes are :—

The number of waves in ten seconds.
The period of some large wave or T.
The maximum amplitude or a.
The maximum velocity or V.
The intensity or $\frac{V^2}{a}$

An inspection of the diagrams, on which about 27 intervals equal 10 seconds, shows that it is possible for an observer to make the number of waves occurring in ten seconds differ, according to the particular interval of 10 seconds which is chosen.

In earthquakes where preliminary tremors are prominent, the number of waves constituting these tremors and occurring in ten seconds may be very large, while the waves in an equal period during the true earthquake disturbance might be small. In the former 60 or 70 waves might be counted whilst in the latter 12 or 14. The waves which I have counted are those of considerable amplitude, which constitute the more sensible part of the disturbance. In many places it will be observed that large waves have small ripples superimposed upon them. If these suprimposed waves are large I have counted them, otherwise they have been omitted. The numbers which I give are therefore only approximate. For instance, where 27 waves are counted as having occurred in 10 seconds another observer

may count 26 or 28. From these numbers it is evident that the average period of waves may be calculated.

The period T which I give is that of some large wave for which the amplitude or half semi-oscillation is measured. Here again it is evident that other measurements might be made, but the difference between them and those given would be exceedingly slight.

On the assumption of simple harmonic motion the maximum velocity or $\frac{2\pi a}{T}$ is calculated. This quantity is a measure of the velocity which determines projection.

From the maximum velocity a maximum acceleration $\frac{V^2}{a}$ is calculated, which approximately measures the overturning and shattering power of an earthquake.

For fuller discussion of the experiments which led to the adoption of quantity V and $\frac{V^2}{a}$ as measures of important elements in earthquake motion rather than the degrees of Palmieri, or the "velocities of shock" employed by Mallet, see "Seismic Experiments," Transactions of Seismological Society, Vol. VIII.

II.—RECORDS.

1.—March 25th, 1884.—This was, apparently, a very slight earthquake. From enquiries I found that at least nine out of ten persons did not feel it. Professor Fujioka, sitting upstairs in one of the rooms of the Imperial College of Engineering, observed the weights of a clock swinging and thought that there might be an earthquake. My attention was called to the occurrence of this disturbance by His Excellency A. Davydow, the late Russian Minister, who observed his lamps swinging but did not feel any motion. On referring to my instruments, I found that at stations A and B an earthquake of large amplitude but slow period had been recorded (see

diagram). The disturbance does not appear to have been recorded by the instruments at the Imperial Observatory.

An analysis of the diagrams gave the following results :—

	Stations. A. N.S.	A. E.W.	B. N.S.	B. E.W.	C. N.S.	C. E.W.
Number of waves in 10 sec. ...	22		18		—	
Maximum period T	.73		.85		—	
Maximum amplitude (a)	.10		.5		—	
Maximum velocity (V).....	.9		3·7		—	
Intensity $\frac{V^2}{a}$	8		27		—	

Comparing the N.S. waves between the 21st and 25th time intervals as recorded at the two stations, we see that at station A the period is .7 sec. whilst at the latter .64 sec. A point worthy of observation is the great increase in period at the end of the disturbance.

Velocity.—The times of arrival of the waves marked *a b c* at station A before the arrival of the waves *a b* and *c* at station B is .12, .098, and .061 seconds respectively, a mean value for which is .093 seconds. As the distance between A and B is 778 feet, the maximum velocity cannot have exceeded 865 feet per sec. From the character of the diagrams we cannot assume that the disturbance approached A and B in a direction making an angle greater than 45° with the line joining A and B. On such an assumption, after reaching A the disturbance would have 545 feet to travel before reaching B. If this distance was crossed in .093 sec., the velocity must have been about 5,860 feet per sec.

2.—March 31st.—As experienced in my house, the earthquake was long and gentle. For 10 or 15 seconds at the commencement it was so gentle that, had it not been followed by a stronger motion, it would have been difficult to say with certainty that there had been an earthquake. These preliminary tremors are not shown in the diagrams, the plates on which the records were written not having been set into motion sufficiently early.

Palmieri's instrument recorded the shock at 8.22.0 p.m., N.W. 0°.40′, W. 1°.40′, S.W. 1°.20′.

	A.	B.	C.
Number of waves in 10 sec....	36	32	23
Period T	.30	.24	.33
Maximum amplitude a.....	.1	.14	.05
Maximum velocity V	2.1	3.6	.9
Intensity $\frac{V^2}{a}$	44	92	16

The small number of waves observed at Station C is probably due to the smallness of their amplitude, in many places resulting in their coalescence to form a straight line.

In the original plates it would appear that there was a slight similarity between certain waves in the early part of the N.S. motion at stations A and B. It is, however, difficult to recognize similar waves in the diagram taken at station C.

Assuming that similar waves have been recognized there, in three cases the motion reached station B .111, .134, and .106 seconds before reaching station C. The mean value for these intervals is .117 seconds.

The motion reached station A .127 or .050 seconds before reaching station B. The mean of these values is .088 seconds. It is, however, likely on account of the smallness of the diagram at A that there may have been an error in the identification of similar waves.

Assuming the values .117 and .088 seconds to be approximately correct, then the disturbance crossed the observation area coming from the N.W. with a velocity of about 4,270 feet per second.

If, however, we only assume the value .117 seconds to be approximately correct and that the disturbance approached in a N.W. direction (this direction being deduced from the character of the diagrams) we obtain a similar result.

3.—April 16th.—At my house this earthquake was gentle but long. In Igura, which is about a mile distant, it was described as severe. The house resting on 10 inch shells had a

long gentle motion corresponding in period to its own motion when set swinging. Palmieri's record was at 0.23.0 a.m. N. 5°, N.W. 3°, W. 3° 10′, S.W. 2° 10′.

An analysis of the diagrams gave the following results:—

	A.	B.	C.
Number of waves in 10 sec.....	30	25	32
Period T.....	.36	.61	.36
Maximum amplitude a.....	.3	.8	.1
Maximum velocity V	5	8	1.7
Intensity $\frac{V^2}{a}$	83	80	28

Velocity.—In comparing the diagrams from A and B it would appear that the motion had reached B about .13 second before reaching A. This result is based on the examination of 5 different waves each of which appear to be visible at both A and B.

At station C there is only one wave which appears to be reproduced at A (the wave a). Assuming this identification to be correct then the motion at C was felt about 1.2 seconds before being felt at A.

From the first observation the velocity between A and B may have been at the rate of 778 feet in .13 sec. or 5,984 feet per sec.

Taking the observations at A, B and C, in conjunction, then the disturbance advanced from N. 7° W. with a velocity of about 660 feet per second. The probability, however, is that the wave at C did not correspond with the one at A.

4.—May 6th.—At about 5.30 p.m. there was a long earthquake, but not very strong. This I did not feel, as I was then in the garden. A smaller shock, about two hours later, I felt distinctly whilst dining with a friend in Kojimachi.

Palmieri's record was at 5h. 37m. 37s. p.m. N. 3° 20′, W. N.W. 2°.40′, W. 3° 10′., S.W. 4°. There was a second slighter shock at 9h. 0m. 21s. p.m.

9.—May 31st.—Slight shock. Palmieri's instrument, oh. 59m.48s. p.m., N.W. 1° 0′, W. 1° 0′.

	A.	B.
Number of waves in 10 sec.	31	28
Period T.	.35	.30
Maximum amplitude a	.05	.1
Maximum velocity V	.8	2
Intensity $\frac{V^2}{a}$	13	40

10.—June 8th.—At about 10.30 a.m. there was a slight shock, consisting of 3 or 4 quick back and forth movements of small amplitude. This was not recorded at the Observatory by Palmieri's instrument.

11.—June 11th.—A short, sharp shock at about 11 p.m. Palmieri's instrument, 11h. 11m. 02s. p.m., W. 6°.

	A.	B.	D.
Number of waves in 10 sec.	32	26	26
Period T.	.36	.36	.36
Maximum amplitude a	.15	.25	.1
Maximum velocity V	2.7	4.5	1.8
Intensity $\frac{V^2}{a}$	48	81	32

The motion appears to have reached A and D at the same moment. The movement, however reached B about 1¼ ticks (.45 sec.) before reaching A. The identification of similar waves is doubtful. The velocity derived from this is 1,644 feet per second, the disturbance approaching from N. 35 E.

12.—June 14th.—In morning a slight earthquake. Palmieri's instrument, 3h. 29m. 19sec. a.m., N.W. 0° 20′, W. 0° 10′, S.W. 0° 10′.

13.—June 15th.—A slight shock, only just perceptible upstairs. Palmieri's instrument, oh. 6m. 25sec. p.m.

14.—June 18th.—A slight shock at 11h. 19m. 16sec. p.m.

15.—July 2nd.—A slight shock at noon. Not recorded at the Observatory.

16.—September 15th.—There was a small earthquake at 8 a.m. It commenced very gently as a series of tremors lasting

10 or 15 seconds. After this there was a sudden increase in motion. This was followed by a severe typhoon which raged all day. Not recorded at the Observatory.

17.—October 8th.—There was a slight shock in Yokohama at 3h. 46m. 30sec. p.m. At the end of September there were several small shocks. Not recorded in Tōkyō.

18.—October 13th.—At 3h. 16m. 35sec. a.m. there was a strong shock. Palmieri's instrument, N.W. 1° 10′, W. 4° 40.

19.—October 15th.—On this date there was the strongest shock of the year. Plaster fell from roofs and clocks were stopped. One or two chimney's fell. In Tōkyō, Dr. Naumann's chimney at Yamato Yashiki fell. This is close to my house.

Palmieri's instrument, 4h. 21m. 54sec., N. 12° 30′, N.W. 53° 40′, W. 48° 30′, S.W. 95° 10′.

In Yokohama this disturbance was recorded at 4h. 21m. 38s. or 16 seconds before being felt in Tōkyō. Mr. K. Sekiya at the Tōkyō University obtained a record with a maximum range of motion of 42 mm. and a maximum acceleration of 500 mm. per sec. His observatory is situated on the soft alluvium which constitutes the low ground of Tōkyō.

The origin of this earthquake is probably in or near Tôkyô Bay.

20.—October 19th.—About 8.30 p.m. there was a slight shock. At the three stations ripples were just visible.

Palmieri's instrument, 8h. 22m. 47s. p.m. N.W. 1°, W. 1° 40′.

21.—October 24th.—Palmieri's instrument, 8h. 35m. 39s. p.m., W. 1° 20′; duration about 20 sec.

	A.	B.	C.
Number of waves in 10 sec.....	36	30	too small to estimate.
Period T.....	.32	.41	
Maximum amplitude a	.07	.1	
Maximum velocity V.	1.3	1.5	
Intensity $\frac{V^2}{a}$	27	22	

The motion appears to be equally divided between the N.S. and the E.W. components.

22.—November 16th.—I had just taken the reading of a level indicator in the Physical Laboratory, when I observed the pointer of the instrument moving with decided sharp motions about East and West. This movement continued for about 30 seconds, when the motion became more violent, having a range of 30 or 40 millimeters. As the instrument has a multiplication of 80, the true motion must have been about .5 millimeters. The direction of motion was irregular, but chiefly East and West. Sometimes the pointer described ellipses, sometimes it traced a path like the figure 8. After about 6 minutes the forced motion appeared to cease, and the movement was regular, due to a swing of the pendulum. It was 9 minutes before the pointer regained its original position. The change in position of the pointer in this instrument as in two others was about 1 mm. During the disturbance I neither felt a motion or heard a sound. In my own house, however, upstairs, the movement was moderately strong.

Palmieri's instrument, 9h. 51m. 34s. a.m. N. 2°.30′, N.W. 0°.20′, W. 3°.40′, S.W. 0°.10′.

At Hakodate there were two shocks, one at 1.30.20 and the other at 2.15 p.m. The first lasted 40 sec., and the second 3 sec. The first disturbance was sudden and violent. Clocks stopped; articles were thrown down. Warehouses cracked. Altogether, it was one of the most severe shocks felt during recent years.

	A.	B.	C.
Number of waves in 10 sec.....	34	32	38
Period T.....	.47	.47	.23
Maximum amplitude a.....	.25	.3	.05
Maximum velocity V.....	3·5	4	1·3
Intensity $\frac{V^2}{a}$	49	53	34

At A the motion was chiefly E. and W. At B it was slightly more N. and S. than E. and W. At D it was slightly more E. and W. than N. and S.

From the times it is evident that the Hakodate disturbances were not the same as the one recorded in Tōkyō.

At about 10 a.m. there were two shocks felt near Yamagata.

23.—November 21st.

	A.	B.	C.
Number of waves in 10 sec.....	36	35	38
Period T.....	.27	.45	.30
Maximum amplitude a.....	.1	.25	.05
Maximum velocity V.....	2.2	3.5	1
Intensity $\frac{V^2}{a}$	48	49	20

At A the motion was chiefly E.W. At B the motion was equally E.W. and N.S. At D the motion was rather more E.W. than N.S.

24.—November 23rd.—About 11 a.m. there was a long, slow earthquake; whilst standing up it was with difficulty perceptible. In the same room, however, those who were seated felt it distinctly. It made a lamp about 6 feet long swing through an arc of about 6 inches.

Palmieri's instrument recorded two shocks, one at 10h. 50m. a.m., and a second at about 9h. 0m. p.m.

At my house I recorded three shocks, one at 10.53.3 a.m., another at 6.35.0 p.m., and a third at 3.00 a.m. on the 24th. Near Sendai all three shocks were felt sharp and strong.

25.—November 24th.—By Palmieri's instrument, 1h. 37m. 53s. p.m., N.W. 3° 0′, W. 8° 45′. In Yokohama the shock was felt at 1h. 37m. 22s. p.m., the duration being 10 sec.

	A.	B.	D.
Number of waves in 10 sec.	36	28	38
Period T.	.45	.36	.20
Maximum amplitrede a.	.15	.25	.05
Maximum Velocity V.	2	4.4	1.5
Intensity $\frac{V^2}{a}$	27	77	45

At A the motion was almost entirely E.W.

At B the motion was equally E.W. and N.S.

At D the motion was rather more E.W. than N.S.

26.—November 29th.—

	A.	B.	D.
Number of waves in 10 sec.....	26	18	too irregular to estimate.
Period T.....	.36	.56	.4
Maximum amplitude a	.2	.6	.05
Maximum velocity V	3.4	7	.78
Intensity $\frac{V^2}{a}$	57	81	12

At A the motion is almost entirely E.W.

At B the motion is equally E.W. and N.S. At one point there is a movement 1mm. towards the S. and. 4mm. towards the W. This gives a motion of 1.1 m. from N. 23 E. to S. 23 W.

At D the slight but irregular motion is slightly more prominent in the N.S. component than in the E.W. component.

The duration at B would be at least 50 seconds.

27.—December 1st.—About 8.15 a.m. there was a slight earthquake.

Palmieri's instrument, 8h. 11m. 55s. a.m., W. 4°, duration 1m. 05s.

	A.		B.
Number of waves in 10 see.	28	.....	26
Period T.....	.27	.....	.27
Maximum amplitude a.	.35	.....	.25
Maximum Velocity V.....	—	.....	—
Intensity $\frac{V^2}{a}$	—	.....	—

28.—December 6th.—During the early mornring a slight shock, say 2 or 3 a.m.

29.—December 7th.—Palmieri's instrument, 4h. 20m. 14sec., W. 1°, duration 18sec. A second shock at 8h. 34m. 07sec., 4° 10′ N., duration 50sec. This second shock was rather strong. The shock was felt at Shinbashi but not at the Club, where many people were dining. These places are within half a mile of each other.

	A.	B.	D.
Number of waves in 10 sec.....	—	.34	too small to estimate.
Period T.....	—	.24	.24
Maximum amplitude a	—	.2	.05
Maximum velocity V	—	5	1.2
Intensity $\frac{V^2}{a}$	—	125	28

During the night there were other shocks, at 9 and again at 10 p.m. At 8 p.m. two shocks were felt at Shidzuoka.

30.—December 9th.—Palmieri's instrument, 10h. 30m. 56s. p.m., S.W. 0° 55′. Duration 47 seconds. At Sapporo it was very severe, being felt about 10 30.0 p.m.

	A.	D.
Number of vibrations in 10 sec.....	24	24?
Period T.....	.4	.4
Maximum amplitude a	.07	.05
Maximum velocity V	1	.7
Intensity $\frac{V}{a}$.....	14	9

December 16th.—This disturbance was rather strong. Although it did not cause lamps to swing in my house (perhaps owing to the shortness in its period), at a house near the British Legation the intensity was sufficiently great to overturn a lamp.

Palmieri's instrument, 8h. 31m. 9s. p.m., N. 3° 20′, N.W. 3° 20′, W. 5° 30′, S.W. 4° 40′.

	A.	B.	D.
Number of waves in 10 sec.	30	28	40
Period T	.45	.54	.37
Maximum amplitude a	.8	1.2	.25
Maximum velocity V.....	11	14	4.2
Intensity $\frac{V^2}{a}$	151	171	70

At A the motion was practically E. and W. Principal wave 1.5 W. and .3 S.; this indicates the true motion as 1.5 W. and .3 S.; this indicates the true motion as 1.55 mm. N. 76 E.

At B the motion was equally E.W. and N.S. Principal wave 2.5 N. and .3 W. This gives a true motion of 2.55 mm. N. 7 W.

At D the motion is equally E.W. and N.S. Principal wave .5 S. and .6 E. This indicates true motion of .7 m. from N. 45 W.

Velocity.—Assuming the waves a, a, a, to be similar, then the waves at A and B arrived .084 sec. and .186 sec. after reaching D.

The difference in the time of arrival at A and B is .102 sec.

If the waves *b b* are similar, then the difference in the times of arrival at A and B is .183 sec.

The interval between *a* and *b* at A is 1.139 sec., whilst at B it is 1.277. This indicates that as the motion passed from A to B the waves spread out.

32.—December 21st.—A very slight earthquake was felt at Shinagawa.

33.—December 22nd.—Palmieri's instrument, 10h. 34m. 1sec. a.m. N., 3° 20′, N.W. 2° 10′, W. 2° 10′, S.W. 2°, duration 25sec. At my home the shock was moderate. At Yokohama it was felt in the Settlement at 10.30.38.

34.—December 23rd.—A slight shock. Palmieri's instrument, 9h. 06m. 42sec., W. 3° 0′, S.W. 2° 50′, duration 26sec.

	B.
Number of waves in 10 sec.	26
Period *T*.	.4
Maximum amplitude *a*	.1
Maximum velocity *V*	1.5
Intensity $\frac{V^2}{a}$	22

Some of the waves at the end of the disturbance have a period of .7 sec.

This was felt all round the Bay, being strong in Kadzusa; with Kadzusa and Awa added, the area disturbed was like that for map 46. Trans. Seis. Soc. Vol. VII., Pt. 2.*

At 10 p.m. a shock was felt at Wakayama in the South.

35.—December 25th.—Palmieri's instrument 9h. 59m. 29sec. p.m. At Takenawa (a suburb of Tōkyō) it was felt sharply.

36.—December 30th.—Previous to this earthquake, instruments were put up at F and E, whilst the instruments at B and D were interchanged.

As felt in my house, this shock was strong.

A duplex pendulum in my drawing-room indicated a N.S. motion. Palmieri's instrument 1h. 4m. 41sec. a.m., N. 6°,

* All maps referred to are in the same volume.

N.W. 6°, W. 4° 30′, S.W. 5° 20′, duration 49sec. There was also a slight motion felt at my house about 10 a.m.

	A.	E.	D.
Number of waves in 10 sec. ...	32	30 or 16	42
Period T.	.32	.75	.18
Maximum amplitude a	.45	1.9	.2
Maximum velocity V	9	16	7
Intensity $\frac{V^2}{a}$	180	135	245

At A only a partial record of the N.S. component was obtained.

At B only a statical record was obtained indicating an amplitude of 1.5mm. N.S. and .8mm. E. and W.

At E the principal motions E. and W. One motion 2.5 to the N., combined with a motion 1.5 to the W., gives a true motion of 2.9 mm. towards N. 30 W.

The largest motion is 3.6mm. to the West.

At D the motion is equally N.S. and E.W.

The preliminary tremors at E. were performed at the rate of 7 per second.

Comparing A and E, we see that although there was a big amplitude at E the intensity was small.

The distribution was like map 51. At the same time there was a shock at Wakayama.

37.—January 3rd, 1885.—Palmieri's instrument, 2h. 31m. 53sec. a.m., N. 0° 50′, N.W. 0° 50′, W. 2° 55′, S.W. 3° 0′.

	F.	B.	E.	D.
Number of waves in 10 sec.	40	26	40 or 12	26
Period T.	.18	.7	.9	.18
Maximum amplitude a.....	.05	.25	2.5	.05
Maximum velocity V..... ..	1.7	2.2	17	1.7
Intensity $\frac{V^2}{a}$	58	19	116	58

38.—January 8th.—Very slight. Palmieri's instrument, 10h. 27m. 45sec., N. 0° 45′, N.W. 0° 35′, W. 0° 30′.

39.—January 17th.—Palmieri's instrument, 10h. 13m. 59sec. a.m., N. 0° 40′, W. 0° 10′, S.W. 1° 0′. There was a slight

record at the stations A and B. But although the machines were in good working order there was no record visible at F and E. The disturbance was not felt at my house.

40.—January 17th.—Palmieri's instrument, 11h. 20m. 41sec. p.m., N. 0° 25′, N.W. 1° 0′, W. 2° 0′, S.W. 0° 10′. The disturbance was just perceptible at my house.

At F the motion was barely visible, and this only for 2 or 3 seconds. Amplitude, .05mm. Period, .2sec. Motion chiefly N. and S. The motion at right angles to the bank being cut off.

At B motion extends over 13sec. Amplitude, 1mm. Period, .2sec. Direction chiefly E. and W.

At E.—Amplitude, .2mm. Period, .5sec. The motion continues over 15sec. It is altogether N. and S.

At D.—The motion is extremely slight. Amplitude, .04mm. It is chiefly N. and S.

41.—January 24th.—Palmieri's instrument, 9h. 20m. 04s. a.m., N. 2° 20′, N.W. 2° 40′, S.W. 2° 20′, W. 3°40′, duration 16 sec.

At the house on shot the movement was just perceptible.

	F.	B.	E.
Period	.12	·3	·3
Amplitude	.01	.3	.5
Chief Direction of Motion	N. & S.	E. & W.	N. & S.

42.—February 1st, 1885.—In my house this disturbance was felt as a slow, long earthquake. Not recorded by Palmieri's instrument.

	A.	F.	B.	E.
Number of waves in 10 sec.	28	—	20	—
Period T.	·45	—	.82	.5
Maximum amplitude a	.05	..1	.07	.01
Maximum velocity V	.7	—	.6	1.2
Intensity $\frac{V^2}{a}$	10	—	5	14

Where nothing is mentioned, means that the waves were too small for measurement. The above measurements are all made near the commencement of the disturbance. The instrument in the house on shot indicated a series of very small

ripples with an amplitude of .02 mm. Near the end of the disturbance the periods and amplitudes were as follows:—

At A, period .36, amplitude .15.
At E, period .61, amplitude .15.

The increase in period and amplitude in the N.S. component at E on the swampy ground is very noticeable.

43.—February 4th.—Palmieri's instrument, 7h. 52m. 7sec. p.m., N. 1° 20′, N.W. 0° 20′, W. 2° 10′, duration 43sec.

Distribution very similar to map 74. Simultaneously a shock was felt near Nakamura (Station 27).

	A.	F.	B.	E.	House.
Number of waves in 10 sec.....	30	—	30	24	—
Period T.....	.21	—	.30	—	—
Maximum amplitude a	.05	.02	.1	.05	—
Maximum velocity V	1.5	—	2	—	—
Intensity $\frac{V^2}{a}$	45	—	40	—	—

In the above table the omissions indicate that the waves were too small to admit of measurement.

The motion at A and F is chiefly N.S.

At E the motion although chiefly N.S., the E.W. component is also clearly marked. At B the motion is chiefly E.W., with long period waves at the end of the disturbance.

In the house on shot there were some short period ripples indicated.

About 6 a.m. a shock was felt in Shidzuoka.

44.—February 6th.—A stiff shake at 1.34.0. In Yokohama at 1.35.0. The comparison was made by bringing up a watch. Palmieri's instument, 1h. 34m. 57s. p.m., N. 10° 40′, N.W. 8° 40′, W. 7° 0′, S.W. 2.50, duration 57sec. There had been a shock previously at 9h. 40m. 27s. a.m.

45.—February 9th.—Palmieri's instrument, 2h. 03m. 40sec. a.m., N. 4° 20′, N.W. 2° 50′, W. 3° 0′, S.W. 1° 0′.

A duplex pendulum in my drawing-room recorded 1 mm. of motion N.N.E.

46.—February 12th.—The first movements of this earthquake were felt as gentle tremors lasting at least 10 seconds. During this time a lamp about 5 feet long hanging from the ceiling was distinctly seen to be vibrating vertically. After this there came a series of strong horizontal motions. About half an hour before this disturbance, decided changes in level were observed in the level recorders. I recorded the shock at 2h. 56m. 20sec. p.m. Palmieri's instrument, a mile distant, gave a record at 2h. 56m. 58sec. p.m. In Yokohama Mr. Talbot recorded at 2h. 55m. 30sec. p.m. Palmieri's instrument gave records N.S. 7° 20′, N.W. S.E. 8° 20′, E.W. 10°.

Distribution like map 44. Simultaneously shocks were felt in the N.E. Peninsula of Awomori Ken, in the Kii Peninsula, Amakusa, and on the opposite coast of Eastern Shikoku.

	A.	F.	B.	E.	G.
Number of waves in 10 sec.	30	34	28	14	72 (ripples).
Period T	.39	.42	.39	.72	.39 } greatest pos-
Maximum amplitude a	1.2	.7	.8	2.2	.5 } sible values.
Maximum velocity V	19	10.1	13	19	12
Intensity $\frac{V^2}{a}$	300	145	210	170	128

For stations A, F, B, and E, corresponding waves have been taken. These waves have not in all cases been the largest. For instance, there is a wave in E, with a range of 5.5 mm., or 2.7 mm. amplitude.

In the house resting on shot or G there are only two noticeable waves, respectively of about .5 and .4 mm. amplitude. In all other diagrams there are many waves of this amplitude.

If we take 6 successive prominent waves in the E.W. diagram at A, we find by measurement from the diagrams that the average value for a is .4 mm., and the average period .3sec. This gives a maximum velocity of 8.3 mm. per second. This is the velocity which determines the projection of objects.

By a similar calculation for the same waves at E, we find that $a = 1.2$ mm. and $T = .66$sec. This gives a maximum velocity for projection of 11.4 mm.

For the house on shot the maximum velocity is 4.5 mm. From this we see that the *average* maximum velocity of motion sustained by the house is very much less than that experienced at the stations.

The *average* intensity $\frac{V^2}{a}$ at A, E, and G, calculated from the same 6 waves, is respectively 172, 108, and 108 mm. per sec.

If, however, we take the maximum intensity as exhibited at all the stations and the house, they are as seen from the table 300, 145, 210, 170, and 128 millimeters per second,—the last value being that for the house.

From these calculations it would therefore appear that the velocities causing projection, or the accelerations causing overturning, are greater outside the house than they are inside. It may therefore be safely stated that the foundations of this particular house exercise considerable influence in preventing the acquisition of earthquake motion.

The advantage gained by using shot foundations is however seen better by an inspection of the diagrams than from the calculations. From the diagram taken in the house, with the exception of two waves which are marked A and B, the motion has been practically nothing, whilst waves equivalent to A and B repeatedly recur in all the other diagrams. If we were to sum up the motion represented by all the waves recorded in the house and compare it with the motion represented by all the waves recorded at each of the other stations, the result would certainly show that the motion outside the house was very much greater than that which experienced inside the house.

At all stations the violent movements commenced suddenly, after about 10 seconds of tremors. These tremors were in every probability the vertical motion already mentioned.

At A the motion is equally N.S. and E.W.; the chief wave is however nearly from W. to E. At F the motion is for one or two waves equally N.S. and E.W., but after that the movement is principally N.S., that is to say, parallel to the foot of the

slope at the bottom of which station F is situated. Possibly the E.W. component of motion was eliminated by the free surface of the slope to which it advanced at right angles. Compounding the first prominent motion of 1.5m. E. with .9m. S., we obtain a true motion of nearly 1.7mm. S. 63°. E.

At B the motion is equally E.W. and N.S. Compounding the first principal movement of 1.7m. E. and .9m. S., we obtain a true motion of 1.9m. S. 60 E.

At E the motion is chiefly E.W. Combining the first chief movement of 1.5m. E. with .5 S., we obtain a true motion of 1.6 S. 70 E.

It will be observed that these last three directions for the first shock are practically identical.

Velocity.—If the motion reached station F at 0, then it reached B at .039, or .06 later, and E. at .164 or .152 later than at E.

47.—February 27th.—This disturbance was so slight that I did not feel it whilst seated in the college.

Palmieri's instrument, 1h. 37m. 29sec. p.m., N. 1°.30′, N.W. 2° 20′, W. 2°.0′. Distribution like map 102, being strong to the North of Tōkiō.

	A.	B.	E.	House.
Number of waves in 10 sec.	32	32	36	—
Period *T.*	.24	.28	.25	—
Maximum amplitude *a*	.1	.12	.05	.04
Maximum velocity *V*.....	2.6	2.7	1.2	—
Intensity $\frac{V^2}{a}$	67	60	28	—

At A the motion is chiefly W.E., at B it is chiefly N.S., whilst at E it is equally N.S. and W.E.

A duplex pendulum in my drawing-room indicated .3 mm. N.S.

48.—February 28th.—This earthquake was very slight. Palmieri's instrument, 10h. 20m. 05sec. p.m., N. 2° 50′. Distribution over a small area to west of Tōkiō towards Hachioji.

Simultaneously a shock was felt across the middle of the Kii peninsula and the eastern end of Shikoku.

	E.
Number of waves in 10 sec.	50
Period T.	.18
Maximum amplitude	.05
Maximum velocity V	2
Intensity $\frac{V^2}{a}$	80

The remarkable point to be observed is the shortness of the period at the station E upon the marsh. The record obtained in the house on shot has about the same amplitude as that at E. Its period is, however, much greater, averaging .3 sec.

49.—March 12th.—At the time of this earthquake I was sitting alone upstairs. I felt very gentle tremors and saw a lamp vibrating very quickly up and down. This lasted 10 or 15 seconds, after which came a decided shake, and other people in the house first recognized that there was an earthquake. In my drawing-room a duplex pendulum gave a record of .4 mm. about N. and S.

In Yokohama the time was 4h. 22m. 44sec. The shock was sharp but without peculiarities. Felt over a small area parallel to the north side of the Tonegawa near stations 10 and 12.

The directions and intensities were :—

	A.	B.	E.	G.
Number of waves in 10 sec.	30	26	18	48
Period T	.18	.29	.64	.31
Maximum amplitude a	.1	.3	.6	.1
Maximum velocity V	3.4	6	5.8	2
Intensity $\frac{V^2}{a}$	115	120	56	40

The small amount of motion experienced by the house on shot at G is better seen by reference to the diagram, which is little more than a series of small ripples.

50.—March 20th.—Whilst taking lunch at the club in Yokohama at 12h. 58m. 35sec. I felt the earthquake as an easy gentle swinging movement. In Tōkiō it was felt severely.

Distribution very similar to map 44, extending to the west to Kofu.

	A.	J.	B.	E.	H.
Number of waves in 10 sec....	30	26	30	14	12
Period T.....	.44	.55	.53	1.4	.85
Maximum amplitude a.	1.3	1.2	1.4	1.9	.35
Maximum Velocity V.....	18	13	16	8	.25
Intensity $\frac{V^2}{a}$	249	140	182	34	1.7

From the above table it is evident that the projecting effort V at any of the stations was very much greater than it was in the pit H. The same may be said with regard to the overturning efforts.

If we simply compare the motion experienced in the pit with that experienced immediately above it, at the station J, not 20 feet distant, the range of motion ($2a$) in the pit was to that on the surface as 1:43. The maximum velocity at these places being as 1:52, and the maximum accelerations being as 1:82.

The vertical motion recorded at J had a period or an average period of .37sec. with a maximum amplitude of .1mm.

Direction.—At A the preliminary tremors extend over about 5 seconds, after which the motion appears to be equally E.W. and N.S. The first motion was .8 S. and 1.1 W., indicating a true motion of 1.5 W. 40° S. The second lurch was 2.5 S. and 1.5 W., indicating a true motion of 3 W. 60° S.

At J the preliminary tremors continue over a rather longer period than that indicated at A. The first wave was 1.2 S. and .4 E., indicating a true motion of 1.2 S. 20° E. The second wave is 2.3 S. and .5 W., indicating a true motion of 2.3 W. 80° S. The motion is more pronounced on the N.S. component.

At B the preliminary tremors are also recorded as the commencement of the motion, but as the record was lost by the accidental breaking of the original plate it is impossible to compare similar waves. The motion is rather more pronounced in the N.S. component than in the E.W. component.

At E the motion at first is chiefly E.W. Subsequently it is principally N.S.

Velocity.—The intervals in the times of arrival of similar waves at A, J, and B, were as follows:—

	wave *a*.	wave *b*.	
At A	1.99 sec. ...	4.11 sec.	Therefore the wave *a* arrived 1.04 sec. at A before J, while *b* arrived 1.15 sec., and the wave *a* arrived at A 1.12 sec. before reaching B.
At J	3.03 sec. ...	5.26 sec.	
At B	3.11 sec. ...	—	

From the above it would appear that different waves travel with different velocities. This is also indicated by the variation in the period of a given wave as recorded at two stations. For example at A the period of *b* is .44 sec., whilst at J, on harder ground, it becomes .42.

III.—CONCLUSIONS.

1.—Number of Waves in Ten Seconds.

The following table gives the number of waves which have occurred in ten seconds at the different stations. The last line gives average values for these numbers:—

Table I.

Number of Waves in Ten-Seconds.

1884-1885.	A	B	C	D	E	F	G HO SE	H PIT	J	
March 25th	22	18	.....	.....	.....	.....	.....	.....	...	
March 31st	36	32	23	.....	.....	.....	.....	.....	...	
April 6th	30	25	32	.....	.....	.....	.....	.....	...	
May 6th	32	26	35	.....	.....	.....	.....	.....	...	
May 11th	30	27	35	.....	.....	.....	.....	.....	...	
May 19th	37	33	21	.....	.....	.....	.....	.....	...	
May 19th	22	26	.....	.....	.....	.....	.....	.....	...	
May 30th	28	21	.....	.....	.....	.....	.....	.....	...	
May 31st	31	28	.....	.....	.....	.....	.....	.....	...	
June 11th	32	26	.....	26	.....	.....	.....	.....	...	
October 24th	36	30	.....	.....	.....	.....	.....	.....	...	
November 10th	34	32	.....	38	.....	.....	.....	.....	...	
November 21st	30	35	.....	38	.....	.....	.....	.....	...	
November 27th	36	28	.....	38	.....	.....	.....	.....	...	
November 29th	26	18	.....	.....	.....	.....	.....	.....	...	At D too irregular to estimate.
December 7th	.....	34	.....	.....	.....	.....	.....	.....	...	At D too small to estimate.
December 9th	24	.....	.....	24	.....	.....	.....	.....	...	
December 10th	30	28	.....	40	.....	.....	.....	.....	...	
December 23rd	.....	26	.....	.....	.....	.....	.....	.....	...	Round Tōkyō Bay, strong Kadzusa.
December 30th	32	.....	.....	42	30 or 16	.....	.....	.....	...	
January 2nd	.....	26	.....	26	40 or 12	40	.....	.....	...	
February 1st	28	20	.....	.....	.....	.....	.....	.....	...	N.W. quake.
February 4th	30	30	.....	.....	24	.....	.....	.....	...	
February 12th	30	28	.....	.....	14	34	72	.....	...	Ripples.
February 27th	32	32	.....	.....	36	.....	.....	.....	...	
February 28th	.....	.....	.....	.....	50	.....	.....	.....	...	
March 12th	30	26	.....	.....	18	.....	48	.....	...	
March 20th	30	30	.....	.....	14	.....	.....	12	26	
Average	30	28	29	34	23 or 28	37	60	12	26	

Whilst the shortest period has been at stations like C and D, situated on comparatively hard ground.

3.—Maximum Amplitude in Millimeters.

The amplitudes recorded in the following table are measured on the same waves which were used in calculating the periods in the last table :—

Table III.

Maximum Amplitude in Millimeters.

1884-1885.	A	B	C	D	E	F	G HOUSE	H PIT	J
March 25th	.10	.5							
March 31st	.1	.14	.05						
April 6th	.3	.8	.1						
May 6th	.4	1	.1						
May 11th	.3	.9	.1						
May 19th	.07	.15	.04						
May 19th	.1	.2	.02						
May 30th	.05	.1							
May 31st	.05	.1							
June 11th	.15	.25		.1					
October 24th	.07	.1							
November 16th	.25	.3		.05					
November 21th	.1	.25		.05					
November 27th	.15	.25		.05					
November 29th	.2	.6		.05					
December 7th	.1	.2		.05					
December 9th	.07			.05					
December 16th	.8	1.2		.25					
December 23rd		.1							
December 30th	.45			.2	1.9				
January 2nd		.25		.05	2 5				
February 1st	.05	.07			.1	.05			
February 4th	.05	.1			.05	.01	.05		
February 12th	1.2	.8			2.2	.02	.5		
February 27th	.1	.12			.05	.7	04.		
February 28th					.05				
March 12th	.1	.3			.6		.1		
March 20th	1.3	1.4			1.9			.035	1.2
Average	.37	.40	.07	.09	.95	.19	.17	.035	1.2

The first point to be noticed in the above table is the great range of motion observed at any given station in different earthquakes. Although the greatest range of motion usually occurs upon the soft ground, this is not invariably the case. For very small earthquakes it would appear that sometimes the soft ground appeared to absorb the motion, and the record obtained would be less than upon neighbouring hard ground. In moderately strong earthquakes, however, the motion on the

soft ground has been invariably very much greater than on the hard ground.

Comparing together the range of motion at any two stations, as far instance A and B, we see that although the motion has always been greater at B, yet the ratio of the amplitudes at these two stations has varied within considerable limits.

One explanation for these differences may possibly be due to the side from which the motion has approached these stations. The small amplitudes recorded at F are remarkable, inasmuch as this station is situated on soft ground. This station was, however, at the foot of a slope running N. and S., and in consequence it is possible that the E. and W. component may have been eliminated, whilst only the N. and S. motion parallel to the length of the bank was recorded.

4.—Relation of Amplitude and Period.

A striking feature in all earthquake diagrams which I have obtained is the variability in the period of the motion. The smaller the amplitude the shorter is the period.

Taking a number of successive waves in different diagrams, it appears that the period inceases very rapidly until the amplitude becomes large, after which the period ceases to increase or increases very slowly. The rate of this increase apparently depends upon the nature of the ground. Thus, at station B in the earthquake of March 25th, after the amplitude reaches 5 or 6 millimeters the increase in period is slight—up to this amplitude the increase in period is rapid.

These observations have considerable bearing on the maximum velocity and maximum acceleration as experienced in hard ground as compared with soft ground. The greater distructive effort in soft ground arises from the fact that the length of period is more than counterbalanced by the largeness of the amplitude.

5.—Maximum Velocity in Millimeters per Second.

The following table is calculated on the assumption of simple harmonic motion from the quantities given in the two preceding tables:—

Table IV.

Maximum Velocity in Millimeters per Second.

1884-1815.	A	B	C	D	E	F	G HOUSE	H PIT	J
March 25th	.9	3.7							
March 31st	2.1	3.6	.9						
April 6th	5	8	1.7						
May 6th	5.3	9	1.7						
May 11th	6	12	2.4						
May 19th	1.8	2.6	1.2						
May 19th	1.5	2.5							
May 30th	.9	1.5							
May 31st	.8	2							
June 11th	2.7	4.5		1.8					
October 24th	1.3	1.5							
November 16th	3.5	4		1.3					
November 21st	2.2	3.5		1					
November 27th	2	4.4		1.5					
November 29th	3.4	7		.78					
December 7th		5		1.2					
December 9th	1			.7					
December 16th	11	14		4.2					
December 23rd		1.5							
December 30th	9			7	16				
January 2nd		2.2		1.7	17	1.7			
February 1st	.7	.6			1.2				
February 4th	1.5	2							
February 12th	19	13			19	10.1	12		
February 27th	2.6	2.7			1.2				
February 28th					2		2		
March 12th	3.4	6			5.8				
March 20th	18	16			8			.25	13
Average	4.4	5.3	1.6	1.4	8.7	5.9	7	.25	13

An inspection of the above table shows that the greatest projecting power was experienced at E and the least at C and D, that is to say, the greatest destruction due to projection might be expected in the soft ground. The greatest maximum velocity recorded is only 19 millimeters per second.

6.—Maximum Acceleration in Millimeters per Second.

The figures given in the following table are calculated from

the table of maximum velocities and the table of maximum amplitudes:—

TABLE V.

MAXIMUM ACCELERATION IN MILLIMETERS PER SECOND.—(INTENSITY.)

1884-1885.	A	B	C	D	E	F	G HOUSE	H PIT	J
March 25th	3	27							
March 31st	44	92	16						
April 6th	83	80	28						
May 6th	70	81	28						
May 11th	120	160	57						
May 19th	40	45	38						
May 19th	22	31							
May 30th	16	22							
May 31st	13	40							
June 11th	48	81		32					
October 24th	27	22							
November 16th	49	53		34					
November 21st	48	49		20					
November 27th	27	77		45					
November 29th	57	81		12					
December 7th		125		28					
December 9th	14			9					
December 16th	151	171		70					
December 23rd		22							
December 30th	180			245?	135				
January 2nd		19		58	116	58			
February 1st	10	5			14				
February 4th	45	40							
February 12th	300	210			170	145	128		
February 27th	67	60			28				
February 28th					80				
March 12th	115	120			56		40		
March 20th	249	182			34			1.7	140
Average	75	75	33	55	79	101	84	1.7	140

Here, again, we see that the greatest acceleration which may be regarded as a fair measure of the shattering and overturning power of an earthquake, occurred on the softest ground, or at station E.

The greatest acceleration recorded was on February 12th, when at A it reached 300 millimeters, or about 1 foot per second.

When looking at the foregoing tables it must be noticed that the number of records at F, G, H, and J are too few to give average results. At F it will be observed that the records were usually as small as those obtained at C and D, although F was situated on soft ground. The only suggestion that I can offer to account for this is the fact that station F was situated at the foot of a slope, which cut off a greater portion

of the motion advancing from the side of the higher ground at right angles to the direction of the length of the slope.

7.—House Resting on Shot.

As I have already stated, this experiment was very simila- to one carried out by Mr. David Stevenson in the arrangements he made for the lamp tables at several of the lighthouses on the coast of Japan. My experiments, when supporting the house in the way Mr. Stevenson supported his tables, although partially mitigating the suddenness of earthquake motion, were practically failures. The causes leading to failure were chiefly due to a surging movement produced at the time of an earthquake, the movements produced by persons moving about inside the building, and the movements produced by wind. Mr. Stevenson (*Nature*, August 6th, 1884) considers his tables successful. Where they were used, destruction has not occurred, but where they have not been used destruction has occurred. From all the facts that I can gather, Mr. Stevenson's tables appear to have been extremely unsuccessful; when they were used destruction has occurred, and where they were not used no destruction has taken place.

Brunton, in his paper on the Japan Lights (see Institute of Civil Engineers, No. 1,451, p. 9), tells us that shortly after erection, the free motion of the tables occasioned so much inconvenience that they had to be clamped, and for this reason Mr. Stevenson's arrangement was not adopted in lighthouses which were subsequently erected.

From enquiries at the Lighthouse Department, I find that Mr. Stevenson's arrangements were not in working order for at least 10 years, but, in 1882, wishing to give the tables another trial, several of them were put in working order. The result has been that on March 11th, 1882, at Tsurigisaki, where there was a table in working order, a number of the lamp-glasses on the burners were overthrown.

Sometime after a second shock produced a similar effect.

At neighbouring lighthouses, of which these are several (two being within 8 miles) not provided with aseismatic tables, no damage was sustained. The shock of March 11th was severe. It was felt for at least 300 miles along the coast. At Yokohama and Tōkyō, which are at no great distance from Tsurugi-saki, the effects of the shock were carefully recorded. I am not aware that any small articles like lamp-glasses, bottles, and vases inside ordinary houses, were overthrown (see Trans. Seis. Soc. Vol. VII. Pt. 2 p. 41-44). The fact that no ill effects have been felt at other lighthouses provided with Mr. Stevenson's tables, like those in the Inland Sea and near Kiu-shiu, must not be regarded as an argument in favour of Mr. Stevenson's tables, insomuch as the earthquakes referred to were not felt in those districts.

As a further confirmation of the fact that an aseismatic joint made of balls, although theoretically of considerable value, is practically a failure, I may say that all persons who are acquainted with the lighthouse tables with whom I have spoken refer to them as failures. The only form of aseismatic joint which I have found successful has been one where something more like a layer of cast iron sand rather than a bed of balls has been used to break the continuity between a structure and its foundations. In consequence of experiments already detailed, I am led to the opinion that a light one-storied structure may with advantage be rested on layers of cast iron shot, especially perhaps on soft or marshy ground where a hard foundation cannot be obtained. The advantage to be gained is clearly shown in the account of the earthquake of February 12th, 1884. At some future time I hope to make experiments on a building resting on a layer of sand and gravel. Mr. James Bissett, of Yokohama, has suggested to me an actual foundation on sand or gravel. His suggestion is certainly deserving of attention.

8.—Observations in a Pit.

The observations which I have made in a pit led to results which were certainly unexpected. Until these experi-

ments have been repeated and amplified the results they appear to indicate must be received with caution. First, it would appear that an earthquake's motion at a distance from its origin is practically superficial. Secondly it would seem that a building the foundalious of which rose freely from hard ground at the bottom of a deep trench ought to feel but little earthquake movement. Thirdly, taking the experiments made in the pit in conjunction with those made on the surface, it appears that although a station situated immediately behind a trench on the side opposite to that on which the movements advance may be in shadow, a station at some distance behind the trench may receive considerable movement.

9.—Practical Conclusions.

The practical conclusions to be derived from what I have now given in detail are that there are at least three ways in which a considerable portion of the movement of an ordinary building may be avoided.

The first method of avoiding earthquake motion in a given district is to make a seismic survey of that area and then select the locality where the least motion is experienced.

A second method by which motion may be cut off from a building is to rest it at each of its piers upon layers of cast iron shot.

A third method, which is applicable to heavy structures of stone or brick, is to allow them to rise freely from foundations on hard ground rising from a deep pit or series of trenches.

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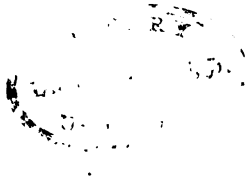

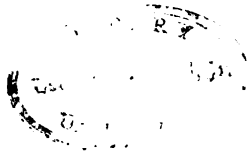

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EARTHQUAKES IN CHINA.

By Dr. J. Macgowan.

[Read March 19th, 1886.]

I had prepared, for presentation to the Seismological Society of Japan, a tabulated account of earthquakes that have been recorded since the Confucian era in Chinese Annals, but it was destroyed by fire during a riot last winter, and with the paper were destroyed also the works from which the facts were derived. Perhaps, however, some general remarks which those records suggest may not be devoid of value.

Nothing can be inferred anent the relative frequency and distinctiveness of earthquakes in ancient and modern times from Chinese history; from the earliest named earthquake, that of Mount T'ai in Shantung, 1831 B.C., to the commencement of the Han dynasty, 200 B.C., only twelve are recorded; tradition, and written archives, noting those only that presented extraordinury features,—a bald list, merely mentioning a disturbance of the rivers Jo So (1808) in Honan, of the Wei, Chin and So, in Shansi (778 B.C.); formation of long chasms in the loess (in 345 and in 206 B.C.) etc. From the Han period onward notices of similar phenomena increase of course, accompanied betimes with a few details mainly relating to loss of life and succour afforded to survivors. Geographically considered, earthquakes in China may be grouped as insular, littoral, and inland.

On the island of Formosa earthquakes are hardly less frequent than in Japan, while on Hainan they are comparatively of rare occurrence, These islands form a portion the great volcanic chain that girdles the coast of Eastern Asia, the

Chinese portion rising from the hundred fathom submarine plateau that overlooks the profound abyss of the Pacific ocean.

Insular earthquakes affect the mainland but seldom and to a slight extent, although so near the least stable portion of the earth's surface. Formosan throes extend across the channel, which is fifty-two fathoms deep and sixty-three miles wide. Japanese earthquakes are rarely if ever felt on the adjacent peninsula. The Korean strait is twenty-six miles wide and ninety-three fathoms in depth. The facts lately made known by Professor Milne, that earthquakes in Japan largely disturb alluvial regions, and that eighty-four per cent. of the whole number originate in the Pacific, partially explain Korean exemption from the shakes of the contiguous archipelago.

The absence, from Chinese and Korean annals, of all reference to earthquakes in that peninsula, long inclined me to regard Korea as comparatively exempt from seismic action, and recently I addressed Consul E. H. Parker of H.B.M.'s Service in that country for information, who obtained from the prefect of Chemulpo a communication on the subject, the purport of which is, that earthquakes are so infrequent and harmless, that records are not made of their occurrence. It is more than ten years since an earthquake was experienced in that kingdom, and on that occasion no one was injured nor were buildings thrown down. No information is obtainable on the subject from Manchuria, where presumably earthquakes are uncommon. There is, however, a record of a volcanic eruption having occurred about a century ago in that portion of the empire.

The only existing volcanic action on islands off this coast is on the north of Formosa, near Keelung, where a solfatara is in ceaseless ebullition, affording large supplies of sulphur, and emitting, during earthquakes, so much hydro-sulphuric gas as to occasion malaise to the residents and to discolor the white paint of ships.

Information respecting Formosan earthquakes is so scant,

that the following from a Chinese writer is worth citing. It relates to an earthquake that occured in northern Formosa in the 5th month of 1693. "During that month the earth shook without cessation. A tract of country in which three villages were situated caved in; the inhabitants, however, had time to escape." Three years after that submergence, the narrator, a mandarin who was on his way to procure sulphur from the solfatara, "could see in a lakelet, where the water was shallow, the tops of bamboos and trees of those villages. While near the solfatara, he heard for a day and night noises that resembled a cataract precipitated from a lofty cliff; the sound seemed to be near and all about, but no evidence of the cause of the noise was discoverable. When, however, he arrived at the geyser, the mystery was explained; he there heard the same sounds like a rushing of subterranean waters."

Formosan earthquakes occasionally cause tremors to be felt on the mainland. These have the ordinary direction of earthquakes on that island, which are generally from N.E. to S.W. or the reverse in the North, and in Southern Formosa run north and south. The Liu-chiu group is the centre of seismic forces that do not appear to extend beyond those islands.

Submarine disturbances not unfrequently attend the insular earthquakes. The sea sometimes rises on the Formosan coast sixteen feet above the usual high tide level. Independently of the terrene commotions of Formosa, its adjacent waters appear to be subject to submarine agitations, occasioning what records of the mainland style "third" or supplemetary tides; but these are of rare occurrence. The "tide-rips" that have attracted the attention of hydrographers are notable phenomena, but the following, from a local gazetteer, seems to indicate the existence of phenomena that cannot be referred to tidal action. "Peculiar noises of the sea are sometimes heard which are commonly regarded as indicative of change of weather, sounds from the North foreboding rain, those from the South being followed by wind. Hissing noises are heard; at times they are low, at

others loud ; when low, they resemble the beating of a drum or the dropping of beans on that instrument ; now, the sounds are near, anon they are distant ; stopping suddenly or continuing for hours. When the noise is loud, it is more noisy than the voices of a hundred thousand men, and the sea bubbles up ; in very protracted cases, the noises continue day and night for half a month ; and when of short continuance, the sound lasts three or four days. Coastlanders err in supposing that these noises have connection with the weather. They are observable during rains and in drought, in wind and in calms. During the sounds, the sea is agitated by fearful billows and furious waves." If that extraordinary seething and roaring of the ocean were synchronous with earthquakes, the fact could not have escaped observation ; undubitably that graphic description applies to submarine volcanic action ; to which, also, I attribute the supplementary tides of the adjacent coast. Some thirty years ago an island was thrown up by a submarine volcano on the South of Formosa. The pumice that is cast upon the northern shore of that island is evidently a submarine production.*

As proximity to the belt of volcanic islands seldom disturbs the mainland of the northern littoral, so the adjacent coast of Southern China and Annam enjoy like exemption from insular throes. Chehkiang and Fuhkien are sometimes slightly joined by Formosan shocks, and even the Canton coast slightly, but Philippine earthquakes never affect Annam.

Earthquakes on the coast of China are frequent, but slight and harmless. Their harmlessness is evinced by the tall slender pagodas that adorn the hills and valleys, and they are generally very limited in area, with great diversity of direction, but a majority being from S.W. to N.E.

Kwangtung and Kwangsi are very rarely subject to earth tremors, and Tonking never. Observing the rarity of seismic

* For an account of the volcanic region of Northern Formosa, see Mr. Hancock, in Imperial Maritime Reports, 1881.

phenomena in the records of Southern China, I enquired of M. Legrand, of Haiphong, who informs me that, since the French became aequainted with the province of Annam, no earthquakes have been experienced, nor, on inquiry, could natives be found who had heard of an occurrence of the kind. I am of opinion that Indo-China generally is exempt from earthquakes.

The tremors that are experienced in Chehkiang, Kiangsu, aud coterminous regions to the West, are sometimes followed by the appearance on the ground of substances that in Chinese books are styled "white hairs, several inches in length, like horse-tail hair."

When I first called attention to records of that kind that are found in local gazzeteers, I suggested that they might be crystals precipitated by gaseous emissions, such as were once reported as occurring after an earthquake in the South-west of the United States. From later descriptions of these "horsetail like" substances, I incline to the opinion that they are organic, perhaps mycillium.

In the summer of 1878 the vernacular press gave an account of the occurrence of the phenomena at Wusoh, a city on the grand canal, 30 miles North of Suchau. "At noon, June 12th of that year, shocks of an earthquake were experienced which lasted several minutes (lit. 'for the space of time taken in swallowing half a bowl of rice'). The motion was so great that sitting or standing was difficult; but no harm was done. Two days later, at night, there was a severer shock, after which within and without the wall of the city, white hairs resembling a silvery beard about three inches in length were found, which boys pulled out of the ground, gathering a handfull in a short space of time." My list of Chinese earthquakes for the past two thousand years having been nearly all destroyed by fire, I am unable to indicate the regions in which earthquakes were followed by the emission of "hairs," but my impression is that all, or nearly all, are alluvial vallies.

The chief foci of inland earthquakes are Szechuen, Shensi, and Kansuh, and less frequently Shansi, Chihli, Shantung, and the central provinces, where the intensity of seismic action is greater than in other portions of the empire and frequently presents continuous or protracted movements; for example a series of earthquakes occurred at Taiyuan, the capital of Shansi, in 1882, followed by shocks at brief intervals for a year. An earlier series occurred in the province of Chihli; the district city of Ch'üchow suffered most, not a house remained standing, and many lives were destroyed; frequent shocks occurred for a year after. The province of Szechuen is also liable to a continuance of seismic throes; one of these commenced in the fourth month 1462, and continued eleven months,—there were in all 375 shocks.

In the loess formation of Northern China (discovered and described by Baron Richthofen) the land is not unfrequently riven by earthquakes forming long narrow chasms of unknown depth that gradually disappear, due to the vertical cleavage and unstratified nature of loess.

In the first decade of the 4th month, 1828, an earthquake caused a fissure over three miles in length and 20 to 30 feet broad, from which a vapour issued that proved fatal to many; people, animals, houses and tombs were engulfed. About two months later, during heavy rains, the chasm gradually filled up.

The earthquake region of China lies in a great seismic zone, which extends from near the Gulf of Chihli to the shores of the Caspian, including Turkestan and the Uralo-Caspian depression. In Eastern Turkestan they present a periodic character, five per annum with remarkable regularity; yet there are few portions of the world so far removed from active volcanoes. Recent Russian exploration has discovered that the supposed Tienshan volcano is merely a solfatara or an ignited coalfield. Among the observations of officers appointed by the Emperor Chien-lung to examine the newly subjugated territory in reference to these "fire-fields," there are several to the following

effect:—"Three days travel to the East of Okishu and to the South of the hill at Palikeh there are several fire-fields. The ground is a red color, and a number of variegated stones are piled upon each other in the neighbourhood, from the middle of which flames upwards of a foot in height are emitted. They are alternately extinguished and lighted up, while the smell is so strong as to render a near approach to the place impossible. For a distance of about 10 *li* not a blade of grass, not an inch of wood, nor a drop of water can be seen. From the peculiar smell of the fire thus raised it is imagined that the soil must be strongly impregnated with sulphur."

The same work represents earthquakes as so common in Eastern Turkestan and the desert, that to the inhabitants "they are not considered strong; four or five occur every year; even when violent, they merely cause the doors and windows to rattle, but, on account of the firm and coherent character of the soil and the thick walls and light roofs in common use, the houses are never thrown down."†

A recent English traveller‡ makes a similar statement respecting Central-Asian earthquakes generally. "At Tashkend they generally average five in a year, but are so slight as not to be noticed by anybody." In that part of the world earthquakes appears to be more frequent at the close of the cold season. In the western portion of the seismic zone, they are of greatest frequency and violence in mountain regions.

Anent the opinion of Mr. Perry, that a maximum of earthquakes is coincident with the mean perigee, I submit the following statistical fragment that escaped the fire referred to. It is partially confirmatory of Professor Milne's observations that cold weather furnishes the maximum of frequency.

List of 738 continental shocks:—

1st month	65	7th month	70
2nd month	82	8th month	70
3rd month	72	9th month	56
4th month	49	10th month	43
5th month	46	11th month	65
6th month	63	12th month	88

† Shanghai Almanac, 1854.
‡ Landsell's Russian Central Asia, 1885.

(The first day of the first month occurs about February 6th, or at the new moon which falls nearest to the point when the sun is in the 15th degree of Aquarius). In their seismic records, the Chinese seldom designate the day of the month (moon) when earthquakes occur. Yet a considerable number may be found; seventy-two cases show twice as many in the first and second as in the third and fourth quarters of the moon's phases; forty-eight in the former period and twenty-four in the latter; the 6th day shows the largest number, 12; none took place on the 2nd, 5th, 13rd and 14th: one occurred on each of the following: 4th, 7th, 17th, 20th, 22nd, 23rd, 24th, 28th, 29th. Hours are rarely given; so far as they go, they show that a large majority are nocturnal.

SUPPLEMENTARY NOTE ON EARTHQUAKES IN CHINA.

DATE.	PLACE.	DIRECTION.	DURATION.	CHARACTER.	AUTHORITY.
1.—March 19th, 5 p.m.	Formosa, S. Cape, N.L. 21° 53′—25° 16′, E.L. 120° 15′—120° 4′	N. to S.	9″	General oscillation	J. R. Harding.
2.—March 25th, night	Foochow, N.L. 26° 02′ 24″, E L. 119° 25′			Two shocks, cloudy with rainy aspect	Foochow Herald.
3.—May 27th, 11 a.m.	Formosa	S. to N.			Hongkong papers.
	Foochow		15″	Seven shocks	Foochow Herald.
4.—June 3rd, 1 p.m.	Foochow			Slight, less so on the coast	Foochow Herald.
5.—July 29th, 9 p.m.	Chungking, N.L. 29° 42′ 10″, E.L. 106° 42′			Rather severe, with dense fog and sulphurous odour	Père Dechevrens.
6.—August 11th, 2 p.m.	Ningpo, N.L. 31° 24′ 29″, E.L. 121° 32′ 02″			Slight	Shenpao.
	Shanghai			Slight	Shenpao.
	Soochow, N.L. 31° 23′ 25″, E.L. 120° 25′ 25″			Slight	Shenpao.
7.—Sept. 12th, 11.30 p.m.	Wênchow, N.L. 28° 02′ 15″, E.L 120° 49′ 37″			Two slight shocks	Natives.
8.—Sept. 22nd, midnight	Amoy, N.L. 24° 31′ 07″, E.L. 117° 03′ 38″			Two slight shocks	Amoy Gazette.
9.—Sept. 23rd, 10 p m.	Ningpo		2″	Three shocks	Shenpao.
10.—Sept. 29th, 9 & 11 p.m.	Foochow			Three shocks	Foochow Herald.
11.—Oct. 7th	Foochow			Slight	Foochow Herald.
12.—Oct. 14th. 9 p.m.	Tai-yuen, N.L. 37° 53′ 30″, E.L. 112° 30′ 30″			Slight	General Mesny.
13.—Dec. 2nd	Shenchow, N.L. 38° 06′, E.L. 115° 37′			Calamitous, felt at Paoting, Chuchia, etc.	Imperial Edict and Temperance Union.
14.—Dec. 9th	Formosa			Three shocks, Destructive	Hongkong papers and Mr. Harding.
	Hongkong	E. to W.		Slight	Hongkong papers.
Dec. 9th, 9.50	Amoy		15″	Violent	Amoy Gazette.
Dec. 9th, 10.10	Amoy		20″		Amoy Gazette.
Dec. 9th, 1.40	Amoy			Milder	Amoy Gazette.
Dec. 9th, later	Amoy			A force	Amoy Gazette.
Dec. 9th, 10.30 p.m.	Foochow			Two shocks each 1′	Foochow Herald.
Dec. 9th, Early a.m.	Foochow			Two slight shocks	Foochow Herald.
Dec. 9th, 10.34 & 10.35	Shanghai	E. to W.		Two slight shocks	T. W. Kingsmill.
	Kiukiang, N.L. 29° 54′, E.L. 116° 04′ 30″			Barely perceptible	Consul Jamieson.
15.—Dec. 15th, 9 p.m. to. a.m.	Amoy			Five shocks	Amoy Gazette.
16.—Dec. 10th		S.E. to N.W.		Two shocks, one very severe	
17.—Dec. 12th, night				One slight shock	
18.—Dec. 14th, night		S. to N.		Three shocks	
19.—Dec. 20th, night		S. to N.		Two shocks	

NOTES TO ACCOMPANY SOME THEOREMS IN THE DYNAMICS OF GEOLOGY.

By T. W. Kingsmill, F.G.S., &c.

[Read May 21st, 1886.]

More than ten years ago my faith in some of the more generally received dogmas in geology commenced to give way. I had been brought up to the science mainly on the east coast of Ireland, and was there thrown in daily contact with phenomena which no observant student could fail to recognise as clearly the result of glacial conditions. As a boy, and years before I had made a study of geology, my attention had been irresistibly attracted by the huge erratic blocks which lay scattered over the Wicklow hills, and I gladly accepted the theory of the "Glacial Epoch" as a perfect explanation of the difficulties which had arisen in my mind. With such surroundings, the uniformatist system of Lyall had not unnaturally a special charm for me; and when later one of the stumbling blocks in the way of the interpretation of the history of the past was removed by the grand discovery of Darwin, that in the succession of life, as in the succession of geologic progress, there are no breaks, I hailed the new doctrine as little less than a revelation.

With such antecedents I arrived nearly a quarter of a century ago in China. I was informed that there were profound traces of the "Glacial Epoch" in Hongkong, and that the superficial deposits of the island were a veritable boulder clay. The boulders certainly were there, as likewise they were to be found everywhere along the granite hills characteristic of the coast ranges of southern China. My previous experiences

soon showed me that the phenomena was not glacial, and I was able to convince myself that the so-called boulders were simply the more silicious spherules which had originally formed an integral portion of the solid granite rock, the more basic magma of which had become decomposed to considerable depths. The incident would have been scarcely worth recording had it not been that apparently similar rocks had been accepted by geologists like Belt and Agassiz as evidences of a glacial period within the tropics, and geologists were asked on such insufficient evidence to accept the theory of a general lowering of the earth's superficial temperature during a protracted period. If, however, these theories could be established it might naturally be expected that some of the mountain ranges of central China would afford some evidence in their favour. The evidence all tended in the opposite direction: diligent search showed that all denudation in these regions of which any trace remained had been essentially aqueous. More, the accumulating geological evidence went to show that Northern Asia in latitudes where in Northern Europe glacial conditions are unmistakeable, had not undergone, in modern geologic times at least, a glacial stage.

These conditions naturally excited doubts in the minds of a few of the more advanced students of geology, doubts, however, which in the face of the evident glacial traces visible to the most superficial observer in Northern Europe and America, it was difficult to substantiate by actual proof. Dr. John Evans in his presidential address before the Geological Society of London in 1876 stated as his belief that "as long as there was a possibility, not to say probability of the geographical position of the poles having changed, it is premature to invoke intense glacial periods to account for all the glacial phenomena which have been observed." Towards a similar conclusion my own studies in Eastern Asia had been gradually leading me, and in an address in February 1877 to the North China Branch of Royal Asiatic Society I stated my grounds in full.

Up to this period it was generally held that the interior of the earth was a mass of molten matter not yet cooled from its pristine condition, and the phenomena of earthquakes and volcanoes were readily attributed to the presence of this great mass in a state of fusion. As the mass cooled down gradually by radiation into space it shrank in dimensions, and the crust contracting on this became wrinkled and corrugated, producing the effects of earthquakes and volcanoes, and shaping the surface into continents and oceans with their concomitants of mountain ranges and valleys.

The first serious objections to this theory came from the Mathematicians—notably Sir William Thomson, who pointed out that the theory of internal fluidity was not compatible with known facts, such as the phenomena of the tides and the precession of the equinoxes. The actual amount of radiation, and the consequent secular contraction was found to be too small to account for the observed phenomena, while chemists pointed out the difficulty in supposing a central mass in a state of igneous fusion to be compatible with the existence of a comparatively rigid envelope. The accepted theories were thus found to be at variance with ascertained facts, while it was amply demonstrated that recent geological movements pointed to some deforming force. To refer this force to internal changes was only repeating the Hindu argument of resting the earth on the back of a tortoise; for after all what supported the tortoise in the one case, or produced the internal changes in the other?

About the same time, in the course of other studies, my attention was drawn to M. Henri Tresca's experiments on the behaviour of ordinary materials under compression, and his conclusion that under a certain amount of pressure, varying according to the material, all substances with which we are acquainted become plastic and flow as if they were liquid. Such a pressure we might expect to obtain at a depth of one or two hundred miles from the surface of the earth, and this

condition, removed on the one hand from the perfect mobility of a liquid, and on the other from the assumed rigidity of a solid, seemed compatible with some of the phenomena adduced by Sir William Thomson. If, however, an inert mass incapable of internal reaction were to be substituted for a mobile fluid, it was necessary to look for some external force to account for the observed movements, and the force of gravity, accepted as the cause of oceanic tides, presented itself. The amount of deformation which could apparently be attributed to this cause on close examination seemed insufficient to account for the facts. It seemed, even at that time, to be an ascertained fact that there was a periodicity in the number and intensity of seismic disturbances corresponding with the motion of the earth from aphelion to perihelion, but the difference in the direct differential action of gravity due to the variation in distance was so small as to afford no reasonable explanation of the phenomena. Even increasing the difference to its possible extreme at periods of maximum eccentricity seemed to show so slight an increment as to be altogether out of proportion to the result. By no means, however, could the observed attitude of the oceanic tide be made to fit in with these calculations, and it became evident that a portion of the movement must be absorbed by the earth itself, but a portion still too small to be of any great effect as a disturbing cause.

Putting aside then for a time my calculations as unsatisfaction, I took up again Croll's "Climate and Time." Many geologists of repute had become dissatisfied with the enormous lapse of time demanded by the ultra-uniformatists for the growth even of the later tertiary formations, and were willing to accept his proposed chronology which referred the "Glacial Epoch" to a period of great eccentricity some 200,000 years ago. But a close study of the geology of Asia had confirmed my impression that the glaciated area did not extend to the northern lands of that continent. If a secular lowering of temperature were to be attributed solely to increased eccen-

tricity, Mr. Croll had proved too much, for in such a case the lowering of the temperature must have been more or less constant along the parallels of latitude, a contention certainly not borne out by the facts, for actually it was confined to a comparatively small portion of the earth's surface. But if the evidence as to the extent of the glacial climate were insufficient, there seemed good reason to believe that the period was marked by frequent changes of level. Two if not three oscillations had to be accounted for in the British Isles, and elsewhere contemporaneous deposits borne similar testimony. If then the glaciation of northern Europe took place during a period of great eccentricity of the earth's orbit, we had at least equally strong evidence to prove a contemporaneous period of geologic change. Was there reason to associate this period of alternate elevation and depression with the condition of eccentricity?

The fall of an apple is said to have suggested the theory of gravitation. If instead of an apple a ball of liquid holding together by its internal attraction towards its own centre of gravity should fall towards the earth, is there evidence to indicate that its shape would be altered in the descent? A little thought suggested that as the forward portion of the ball was subjected to a greater pull than the upper, and that this differential attraction increased as the ball descended, the ball must naturally become elongated in the direction of the line of descent; and that if the fall were from a very great height it would eventually reach the earth as a stream of liquid. Now during a period of eccentricity of the orbit the earth does actually fall towards the sun in its course from aphelion to perihelion; at present the fall during the six months is about three million miles, but (accepting Mr. Croll's chronology as correct) during the European glacial period it must have fallen some ten and a half millions. It is true the ball did not fall in a straight line, but for the matter of that neither did the moon in falling towards the earth the exact distance which confirmed the comparison of the falling apple, and we know besides that

a body falling down a perfectly smooth course acquires at any moment the same velocity it would have attained had it descended a like distance in a vertical line. If the earth were a rigid body it could not alter in shape, but a little more consideration will lead to the conclusion that in such a case the waters of the ocean would pile up at the poles of syzygy as the earth approached its perihelion. Experience tells us this does not occur, and we have only the alternative of believing the laws of gravity untrue, or of acknowledging that the earth is not such a rigid body as we supposed.

In the case experimental proof is out of the question; but the laws of gravity, though often complicated in their results, are essentially simple in principle. *One body attracts another directly in proportion to its mass, and inversely as the squares of the distances separating them.* Was it in this instance possible to apply those laws? The calculation fortunately was not very difficult, and it was found that approximately the prolongation of the earth's axis in syzygy would under present conditions amount to about one-third of a mile by the time it had arrived at perihelion. Tresca's experiments had proved the possibility of the earth assuming a new shape under the action of external deforming forces, and our deforming force had at last been found capable of producing a sensible effect. The fancy of Diogenes of Apollonia had come true, and in the earth the philosopher could behold a living entity which possessed its lungs in the stars, and inspired and exhaled in obedience to their attraction.

Although we may not be able to put a theorem to the crucial text of actual experiment, we may arrive at practically the same end by observing whether or not it is capable of offering a reasonable explanation of phenomena hitherto unexplained. The interior of the earth we may assume then to be in a state of plasticity under pressure, while experience teaches us that most of the substances of which the crust is composed are essentially more or less brittle. An explanation was thus at

once offered for the curious fact that the majority of earthquakes hitherto observed had occurred in the winter half of the year, which happened in the vast majority of those recorded at perihelion. When once the form of gravity again was accepted as capable of affecting the shape of the earth the position and distance of the moon had likewise to be taken into consideration, and a further explanation was afforded of another observed fact—that somehow or other there was a relation between earthquake shocks and the state of the tides. It thus became easy to form an opinion as to the true cause of earthquakes and volcanic eruptions. The earth is a plastic mass surrounded with a brittle crust; in swinging round in its orbit it pants and palpitates like a soap bubble, the crust is very unequal in its capacity to bend, and is moreover here and there weakened by old cracks. Sometimes then the brittle crust snaps, and the snap is accompanied by the sudden vibration known as an earthquake shock; sometimes the yielding of the crust is accompanied by so much friction that the temperature of the adjacent rocks is raised to the melting point, and the phenomenon known as a volcanic eruption is the result.

Every earthquake and volcanic eruption then of necessity uses up some definite amount of force, and we can readily see that the only reservoir of force available is the *vis inertiæ* of the daily rotation. Astronomy teaches us that the period is by slow degrees becoming greater, and that some future period the earth may be reduced to the condition of the moon and present always the same hemisphere to the sun. True, the decrease in the velocity of rotation is at the present time extremely slow, amounting to scarcely more than a second in the length of the day in a thousand centuries. Even so small a factor may become of importance when it is capable of acting during the life-time of a planet. Now we can readily understand that if a shock occur on the medial line of rotation, the moments at either side being equal the sole effect will be an instantaneous stagger and a retardation of the daily period in

proportion to the amount of energy withdrawn. If, however, the shock occur north or south of the equatorial line, the moments of rotation north and south being instantaneously unequal, the earth will shift round its axis of rotation, and the poles and equator assume a new geographical (not necessarily astronomical) position.

Now, one of the difficulties with which I started, and which equally struck so eminent a geologist as Dr. Evans, was the occurrence in some localities of glaciated conditions at distances from the poles inexplicable except on the assumption of considerable depressions of temperature, while in other localities at little distances from the poles there was no evidence of any more depression, or in some cases there was apparently evidence of the contrary change. If then we have evolved a machine capable of shifting the earth about its axis of rotation, it may so happen that each point on its surface may at one time or other have been within such distance of the pole as to become subject to glacial conditions, while the temperature and climate of the globe remained constant. It is the opinion of the astronomer in chief at the Russian observatory at Pultowa that a progressive change in the latitude of the building can be observed, while at Greenwich the contrary opinion prevails. Even at Greenwich the latitude concluded at the moment varies from that assumed from the observatory in the last century, and the question has naturally arisen in connexion with the Russian observations whether the difference is due to actual change, or is only apparent, resulting from instrumental errors not detected at the time.

This subject leads, however, to the threshold of another proposition more geological perhaps than seismological,—namely the possibility of timing the position of ancient poles and equators and the discussion of the arguments of the varying intensity from age to age of the manifestations of geoplastic energy. It is impossible in the limits of a single paper to give even an outline of the arguments, most of which are strict

corrollaries from the preceding. There does, however, seem sufficient evidence to justify the assertion that geologic energy is not constant, but varies from age to age; and that while long periods, even during the tertian epoch, have been marked by frequent and violent changes in the distribution of oceans and continents, the present is an age of marked quiescence.

DISCUSSION.

Dr. Cargill G. Knott, who had the privilege of reading Mr. Kingsmill's paper beforehand, entered into a pretty full criticism of certain positions taken up by the author, of which the following is an abstract:—

The portion of the paper which is of special interest to the members of the Seismological Society, is where Mr. Kingsmill suggests an explanation of the annual periodicity of earthquakes. He invokes the aid of what might be called a differential tidal action. Already * the Society has listened to a discussion of the probable relations between earthquakes and tides or tidal stresses in the earth's substance. The present paper takes up the same question, but from an altogether different point of view. The argument is based upon the manner in which a liquid ball might be expected to behave as it fell towards an attracting, tide-producing body. According to Mr. Kingsmill's calculations, quite a large tide should be produced in the waters covering the earth as the earth falls from aphelion to perihelion. There is, of course, such an annual tide, but it is insignificant compared to the diurnal tides. Furthermore, if this annual solar tide is to be at all effective, surely the monthly lunar tide will also have an

*See Paper on *Earthquake Frequency*, by C. G. Knott, D. Sc., F.R.S.E. (Trans. Seismo. Soc. of Japan, Vol. IX. Part 1).

appreciable effect. When Mr. Kingsmill places us in the dilemma of believing the law of gravitation to be untrue, or of believing the earth to be plastic, his reasoning appears far from sound. He evidently expects an annual tide of huge dimensions; but, because there is no evidence of such, assumes that the earth must be itself yielding. Further, although he does not say so explicitly, the only logical end of his argument is that the earth must yield to the whole amount looked for in the ocean movements but not found there. He seems to be quite ignorant of the valuable calculations made with regard to this very subject by G. H. Darwin.

That the annual tidal stresses, small though they are, may have an influence on earthquake frequency is quite a legitimate surmise; but it cannot explain the fact of the annual periodicity of earthquakes. For statistics show that the maximum of earthquake frequency occurs, not at perihelion but at winter time; so that in the southern hemisphere the maximum falls at aphelion. In other words earthquake frequency is largely conditioned by meteorological phenomena; and, so far, there is little evidence that cosmical phenomena have any great effect. Thus, even granting the annual tide to have a seismic influence, we cannot regard it as the cause of the *winter* maximum in earthquake frequency. Here, in short, the theory is irreconcileable with the facts.

EARTHQUAKE OBSERVATIONS OF 1885 IN JAPAN.

By Professor Seikei Sekiya.

[Read May 21st, 1886.]

In Vol. VII. Part II. of the Society's Transactions, there is a valuable paper by Professor John Milne, "On 378 earthquakes observed during two years in North Japan," in which the author describes in full the results of earthquake observations carried out between October 1881, and October 1883, in the country lying within 35° and 44° North Latitude. Subsequently, by his recommendation the authorities of the Imperial Meteorological Bureau decided to make similar observations extending over the whole Empire, and these I have had the honour of superintending.

The arrangements were certainly made on a wider scale, and it is therefore hoped that they are more complete. The Bureau published observation books furnished with directions for reporting seismic phenomena with or without the use of instruments. These were distributed among more than six hundred local officers and private observers throughout the empire, and the reports were transmitted free by the Post Office. From these reports sent in by different observers thus closely stationed, maps have been made showing the disturbed area for every shock, and general results have been published, the summary of which I am going to give in this paper.

Maps of Typical Earthquakes.

Maps I—XII. show some of the typical earthquakes which occurred in different parts of the country—small shocks as well

as large ones. More will be said about these maps when we discuss the area and grouping of shocks.

Table of 482 Earthquakes from which Maps may be delineated.

In order to avoid publishing a map for each earthquake, which would involve considerable expense, Professor J. Milne suggested that the area disturbed by each shock might be determined by means of a map, like Map XIII., in which numerals are put down to show the different stations; besides which there is a table showing, by corresponding figures, the area disturbed. Actually there were over six hundred observing stations, but to avoid confusion on a small map like this, it is marked only up to 247. The table which is at the end of this paper points out stations visited by each shock. For instance, the earthquake of January 31st, 10. p.m. (No. 30 in the table) has 53, 54, 66, 67, 68, 69, 70, and 71 marked down. By referring to those portions of Map XIII. bearing the corresponding figures, we can judge the position and general character of that disturbance. Again the earthquake of March 7th, 0.40.0 a.m., has 218 only marked down, showing that the shock was local. So by similar methods the area disturbed by any other shock may be delineated. In fact the table is the complete record of the areas of disturbance for the whole year.

In the same table the time and area in square miles of each disturbance are given, the time being that near the origin of shocks.

It is very often the case that two districts considerably remote from each other are shaken simultaneously, or within a short interval of time, while the regions lying between them are entirely unaffected. In these cases it is sometimes difficult to determine whether to count the occurence as one or more shocks. I classify them by considering the interval of time and the nature of the disturbed portion of the country.

NUMBER OF EARTHQUAKES AND THEIR DISTRIBUTION.

In the year 1885 there were in all 482 earthquakes in Japan, *i.e.*, 40 in one month or 1.3 shakings per day. From the reports of these 482 shocks Map XIV. was made, in which the seismic activity of each district is represented by shades of colours, the deepest shaded portions being regions most frequently disturbed. In those portions shaded with the same intensity, figures are put in showing the number of shocks that occurred in the same.

It appears from this map that earthquakes were most prevalent this year in the central and northern parts of the main island along the Pacific coast, while in those regions along the Japan Sea they were comparatively few. Speaking of the main island in general, the range of mountains traversing through and forming the backbone of Central Nippon appears, as pointed out by Professor Milne, to divide it into two zones of different seismic activities.

In Kiūshū, Shikokū, and in smaller islands, the number of disturbances were rather small. In Kiūshu the southern portions facing the Pacific ocean are more often shaken than the northern provinces bordering the Japan Sea, which have the same condition as that of the main island.

Earthquakes are quite numerous in the south of Yezo. From the north and central parts we have not received any reports, which may be due to the scantiness of the population and the difficulty of communication.

Those portions of Map XIV., which are uncoloured claim to be entirely free from shocks. Whether they are really so, or the observers have not felt them although there have been earthquakes, it is difficult to say at present. In Tokio the *majority* of shocks pass unfelt by people, while seismographs register them sufficiently to allow measurements, so that it is more than probable that a large number of rather feeble shocks are not reported; and I fully believe that there is no part in

Japan where the ground does not suffer shaking at least seven or eight times in one year.

Area of Disturbance.

The areas of disturbance vary from small tracts of land to several tens of thousand of square miles. Nearly half of these shocks however are only local. Out of 482 earthquakes there were 235 local shocks. Maps II, III., IV., and XII., are examples of such disturbances. On the contrary, there are some whose area is very extensive, such as that of Map XI., which shock extended from the south of Yezo as far as the Plain of Musashi along the whole breadth of the main island disturbing a *land* area of 34,738 square miles.

This year, *large* earthquakes occurred only in Yezo, and in the north and central portions of the main island mostly along the Pacific Ocean.

If we divide 482 earthquakes according to the size of the disturbed land areas, they are :—

1 to 100 square miles	95
100 to 200 square miles	91
200 to 500 square miles	119
500 to 1,000 square miles	58
1,000 to 10,000 square miles	98
10,000 square miles and upward	21
Total	482

The average land area of one disturbance is 1,634 square miles. The aggregate area of disturbance during the year was 787,679* square miles, and taking the total area of the empire to be 147,000 square miles, it is equivalent to saying that the whole of Japan has been shaken 5.4 times in one year.

Relation of Earthquakes to Seasons.

The number of earthquakes and their areas in the different

* A preliminary account of this paper was given by the present writer in "Nature" No. 861, Vol. 33. By closely examining the earthquake reports sent in, he has been induced to make some alteration in the figures given in the above named journal.

months and in the different seasons of the year are shown in the following tables :—

Months.	No.	Area in Square Miles.
January	32	59,643
February	44	101,080
March	37	43,562
April	37	28,268
May	51	61,828
June	43	94,590
July	32	54,589
August	29	36,103
September	45	86,738
October	41	127,074
November	51	24,529
December	40	69,675
Total	482	787,679

Season.	No.	Area.		No.	Area.
Spring	125	133,658	Hot months	237	362,116
Summer	104	185,282	(April-Sept.)		
Autumn	137	238,341	Cold months		
Winter	116	230,398	(Oct.-March)	245	425,563
Total	482	787,679		482	787,679

In February, May, June, September, October, and November the number was larger than, and in January, March, April, July and August it was less than, the average number (40) for one month in the year, while December had its value equal to the average.

If we group these numbers together according to seasons, autumn represents the maximum and summer the minimum. Again, if we group them into hot and cold months we have 237 for the former against 245 for the latter, the difference being only 8.

It has been shown on many previous occasions that earthquakes are much more frequent in cold months than in hot seasons, but in the present year the difference has only been very slight. It must be noted, however, that the request of the Meteorogical Bureau to the local offices to send in observations was made at the end of the previous year, and in some provinces the report system might not have been in full

working order, which may account for the smallness of the number—and the area—in January. If that were so, it may cause some slight changes in the above table.

As to the area disturbed, February, June, September, October, and December had larger value than the average area (65,640 squire miles) for one month, while the remaining months were under that value. Autumn had the maximum and spring the minimum area of disturbance. Again the area of hot months to that of cold months was in the ratio of 1 to 1.2, the difference being more clearly marked than in the case of the number of shocks.

Grouping of Earthquakes and their Origins.

In a great many instances, the extent of disturbance in certain portions of the country is limited to that portion alone, and it does not extend beyond certain boundaries.

In the Plain of Musashi there were 43 disturbances of this nature, in which the shaken portions assumed the somewhat circular form or a segment of a circle with their centres near the shore (stations 82-91, and 98-111) or out in the sea. Maps I. and VI. are examples of these earthquakes. In Kii (stations 168-169) seven earthquakes had very nearly the same area over that part, also shaking Awaji (station 211) and part of Shikoku (212-213); the origin was probably in the straits between these stations or in the sea beyond. Map IX. is an example. Similar examples may be cited in other parts of the country.

Map XIII. shows the origins of all earthquakes. Figures (in large type) in circular or elliptical curves approximately denote the number of earthquakes that have originated from those origins.

In speaking of these origins the curves are not meant necessarily to be the limits within which these origins lay; in some cases the origins may have been very extensive in length and breadth.

Most large earthquakes originate under the sea or near the

shore. Out of 482 earthquakes 305 were of littoral or submarine origin, while the remaining 177 shocks were of land origin, and were mostly local or small disturbances (see Maps II. and III.). There were not many cases in which large earthquakes originated in the interior of the country. Professor Milne arrived at a very similar conclusion.

Relation of Earthquakes to Volcanoes.

In speaking on the above subject, Professor Milne observed that in the immediate vicinity of active and extremely recent volcanoes the seismic activity has been small, and those two phenomena are not directly connected.

The above remark applies, on the whole, to other parts of Japan although there are many exceptions to this statement. In Kiūshū where both active and extinct volcanoes abound, the seismic disturbances are not very frequent, while on the contrary, in Kii (stations 166, 169) and Mino (stations 141, 142, 150,-154) where active volcanoes are unknown, a large number of shocks have been recorded. On the other hand, the district round the Bay of Kagoshima (stations 233, 234, 236), which is itself supposed to be an old crater, with an active volcano in its centre, has been shaken nine times (probably oftener) in a year while the other parts of the island were comparatively at rest. In the vicinity of Osoreyama (a volcano, station 22), in the northern extremity of the main island the people felt 21 local shocks. In the province of Shinano (stations 120,-129) which has one famous volcano besides many extinct ones, several shocks which in a few cases were tolerably severe.

Relation of Upheaval and Subsidence to Earthquakes.

It was pointed out by Professor Milne that earthquakes are more numerous in Eastern Japan where there is abundant evidence of a recent and rapid elevation.

If we travel from the northern extremity of the main island along the Pacific coast toward the south-west as far as Kiushū one can not fail to see many historical and geological evidences

of upheaval, whereas, if we cross to the Japan Sea side, a gradual sinking of the shore, though not so distinct as the elevation on the other side, is to be noticed. In 1885 the seismic disturbances were more numerous on the Pacific or the rising side and less on the Japan Sea or the sinking side.

In conclusion I am glad to add that the authorities of the Imperial Meteorological Observatory are continuing these observations, and the results to be obtained from more years' work of this nature will, I hope, greatly assist the progress of Seismology in general.

NOTE.—By looking over the reports of 1886, which we have thus far received, we expect to get results somewhat different from those of the previous year.

CATALOGUE OF 482 EARTHQUAKES IN 1885.

JANUARY.

1.—January 1st, 6.30.0 a.m., Station 179; 71 square miles.

2.—January 3rd, 2.30.0 a.m., Stations, 81, 83, 84, 85, 86, 87,'88, 89, 90, 91, 96, 98, 99, 100, 101, 102, 103, 104, 105; 4,291 square miles.

3.—January 3rd, 3.0.0 a.m., Station, 55; 369 square miles.

4.—January 8th, 9.58.0 a.m., Station, 65; 149 square miles.

5.—January 8th, 10.0.0 a.m., Stations, 80, 81, 84, 85, 86, 87, 88, 89, 90, 91, 98, 100, 101, 102, 103, 104, 145; 4,120 square miles.

6.—January 8th, 11.30.0 p.m., Station, 23; 493 square miles.

7.—January 13th, 10.0.0 a.m., Stations, 207, 208, 209; 720 square miles.

8.—January 13th, 9.28.0 p.m., Station, 89; 124 square miles.

9.—January 15th, 9.0.0 p.m., Stations, 83,184, 85, 81, 80, 74, 78, 79, 88, 89, 87, 90, 92, 97, 96, 100, 98, 101, 102, 103, 104; 5,458 square miles.

10.—January 16th, 10.15.0 a.m., Station, 79; 493 square miles.

11.—January 17th, 10.0.0 a.m., Stations, 75, 74, 77, 78, 79, 80, 81, 88, 89, 90, 92, 91, 97, 99, 101, 100, 102; 4,197 square miles.

12.—January 17th, 11.0.0 p.m., Stations, 79, 80, 81, 88, 87, 89, 90, 91, 92, 98, 100, 101, 102; 2,828 square miles.

13.—January 18th, 3.22.0 p.m., Station, 125; 695 square miles.

14.—January 19th, 0.05.0 p.m., Station, 83; 344 square miles.

15.—January 20th, 1.0.0 p.m., Station, 124; 101 square miles.

16.—January 20th, 1.33.18 p.m., Station, 144; 72 square miles.

17.—January 20th, 2.20.0 p.m., Station, 89; 493 square miles.

18.—January 20th, 10.20.0 p.m., Station, 131; 149 square miles.

19.—January 24th, 9.30.0 a.m., Stations, 78, 79, 80, 88, 87, 89, 90, 91, 92, 97, 96, 98, 99, 100, 101, 102, 103, 105, 106, 107, 108, 109, 110, 111; 4,892 square miles.

20.—January 2.30.0 a.m., Stations, 140, 139, 138, 141, 142, 144, 151, 152, 153, 150, 154, 155, 156; 3,328 square miles.

21.—January 27th, 2.54.0 a.m., Station, 152; 289 square miles.

22.—January 27th, 6.43.00 a.m., Station, 152; 471 square miles.

23.—January 27th, 4.35.00 p.m., Station, 152; 471 square miles.

24.—January 27th, 6.5.0 p.m., Station, 152; 289 square miles.

25.—January 28th, 2.0.0 a.m., Station, 152; 289 square miles.

26.—January 28th, 3.10.0 a.m., Station, 152; 289 square miles.

27.—January 29th, 5.0.0 a.m., Station, 152; 289 square miles.

28.—January 29th, 10.15.0 a.m., Station, 54; 250 square miles.

29.—January 29th, 10.0.0 p.m., Stations, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 102; 2,732 square miles.

30.—January 31st, about 10.0.0 p.m., Stations, 53, 54, 66, 68, 67, 69, 70, 71; 2,991 square miles.

31.—January 31st, 11.35.0 p.m., Station, 23; 618 square miles.

32.—January 31st, 12.0.0 m.n., Stations, 43, 47, 49, 50, 51, 52, 46, 53, 54, 68, 66, 55, 56, 63, 65, 67, 64, 72, 71, 69, 70, 82, 83, 81, 80, 73, 74, 78, 79, 77, 94, 93, 92, 90, 88, 89, 87, 86, 85, 104, 103, 101, 102, 91, 97, 96, 98, 99, 95, 118, 100; 17,379 square miles.

FEBRUARY.

33.—February 1st, 0.15.0 a.m., Station, 70; 369 square miles.

34.—February 1st, 0.9.55 a.m., Station, 77; 125 square miles.

35.—February 1st, 5.0.0 a.m., Station, 55; 220 square miles.

36.—February 2nd, 0.0.0 a.m., Station, 92; 100 square miles.

37.—February 2nd, 3.2.0 a.m., Stations, 99, 100; 124 square miles.

38.—February 2nd, after 4.0.0 a.m., Stations, 154, 158; 220 square miles.

39.—February 2nd, 9.30.0 a.m., Stations, 157; 368 square miles.

40.—February 2nd, 10.35.0 p.m., Station, 120; 571 square miles.

41.—February 2nd, 4.8.0 p.m., Stations, 79, 88, 89, 90, 91, 92, 98, 100, 101, 102; 1,810 square miles.

42.—February 4th, 6.10.0 p.m., Station, 131; 149 square miles.

43.—February 4th, 7.40.0 p.m., Stations, 83, 81, 80, 88, 84, 85, 86, 87, 89, 90, 81, 98, 102, 100, 101, 103, 104, 105; 3,375 square miles.

44.—February 4th, 8.0.0 p.m., Stations, 54, 68; 470 square miles.

45.—February 6th, 8.5.0 a.m., Station, 152; 344 square miles.

46.—February 6th, 8.10.0 a.m., Station, 152; 344 square miles.

47.—February 6th, 9.40.27 a.m., Station, 100; 71 square miles.

48.—February 6th, 1.34.57 p.m., Stations, 110, 111, 99, 100, 101, 105, 108, 109, 107, 106, 103, 102, 98, 96, 116, 114, 115, 117, 118, 91, 104, 86, 85, 87, 88, 89, 90, 92, 97, 95, 119, 130, 120, 122, 76, 94, 93, 77, 78, 79, 80, 81, 84, 83, 82, 74, 75, 73, 64, 68; 15,429 square miles.

49.—February 6th, 1.20.0 p.m., Station, 54; 141 square miles.

50.—February 6th, 5.50.0 p.m., Stations, 54, 68; 249 square miles.

51.—February 6th, about 11.0.0 p.m., Stations, 178, 148, 149, 174, 177, 181, 179, 147; 2,460 square miles.

52.—February 7th, 1.0.0 a.m., Station, 23; 620 square miles.

53.—February 8th, 0.30.0 a.m., Station, 64; 893 square miles.

54.—February 8th, 4.0.0 a.m., Stations, 217, 218, 219, 200, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 236; 8,562 square miles.

55.—February 9th, 2.0.0 a.m., Stations, 33, 34, 35, 36, 37, 38, 39, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 116, 117, 118, 119, 120; 30,905 square miles.

56.—February 9th, 10.25.23 p.m., Station, 136; 220 square miles.

57.—February 10th, 11.57.0 a.m., Station, 41; 249 square miles.

58.—February 10th, 10.20.00 p.m., Station 125; 322 square miles.

59.—February 12th, 2.56.58 p.m., Stations, 82, 73, 74, 75, 76, 94, 120, 119, 117, 115, 114, 112, 110, 111, 118 95, 93, 77, 78, 79, 80, 81, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108; 13,255 square miles.

60.—February 12th, 3.45.40 p.m., Station, 81; 90 square miles.

61.—February 12th, 5.7.00 p.m., Station, 23; 619 square miles.

62.—February 12th, 4.26.45 p.m., Stations, 165, 166, 167, 168, 169, 170, 171, 172, 173, 211, 176, 212, 213; 4,566 square miles.

63.—February 15th, 1.41.00 p.m., Station, 89; 173 square miles.

64.—February 15th, 3.40.00 p.m., Station, 81; 173 square miles.

65.—February 16th, 5.20.00 p.m., Station, 124; 249 square miles.

66.—February 17th, 1.00.00 p.m., Station, 89; 71 square miles.

67.—February 18th, 1.00.00 a.m., Station, 29; 869 square miles.

68.—February 19th, 4.00.00 a.m., Station, 100, 107; 273 square miles.

69.—February 20th, 9.10.00 a.m., Station, 127; 1,066 square miles.

70.—February 24th, 7.30.00 p.m., Station, 204, 203; 1,142 square miles.

71.—February 25th, 2.30.00 a.m., Station, 81; 298 square miles.

72.—February 26th, 1.43.00 a.m., Station, 51; 124 square miles.

73.—February 27th, 1.30.00 p.m., Stations, 74, 78, 79, 80, 81, 88, 89, 90, 91, 92, 98, 100, 101, 102, 103, 105; 3,845 square miles.

74.—February 27th, 3.10.20 p.m., Station, 86; 100 square miles.

75.—February 28th, 8.30.00 p.m., Stations, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 213; 4,172 square miles.

76.—February 28th, 10.30.00 p.m., Stations 81, 90, 91, 96, 98, 99 100, 102; 1,269 square miles.

MARCH.

77.—March 3rd, 4.5.0 p.m., Station, 203; 298 square miles.

78.—March 5th, 7.3.0 p.m., Station, 51; 149 square miles.

79.—March 5th, 6.30.0 p.m., Station, 59; 273 square miles.

80.—March 5th, 8.25.0 p.m., Station, 70; 893 square miles.

81.—March 7th, 0.40.0 a.m., Station, 218; 124 square miles.

82.—March 8th, 5.40.0 a.m., Stations, 4, 18; 221 square miles.

83.—March 8th, 6.55.0 a.m., Station, 23; 643 square miles.

84.—March 8th, after 7.0.0 p.m., Station, 100; 71 square miles.

85.—March 8th, 9.30.0 p.m., Stations, 85, 86; 71 square miles.

86.—March 8th, 10.15.10 p.m., Station, 104; 71 square miles.

87.—March 11th, 3.30.0 a.m.; Stations, 216, 222; 495 square miles.

88.—March 12th, 4.8.13 p.m.; Stations, 74, 78, 79, 80, 81, 84, 88, 89, 87, 90, 91, 92, 97, 98, 100, 101, 102; 4,714 square miles.

89.—March 13th, 8.42.30 p.m., Station, 57; 149 square miles.

90.—March 17th, 11.44.57 a.m., Stations, 144, 146; 1,119 square miles.

91.—March 17th, 0.15.0 p.m., Stations, 78, 79; 250 square miles.

92.—March 20th, 10.15.0 a.m., Stations, 74, 77; 571 square miles.

93.—March 20th, 0.0.5 p.m., Station 107; 78 square miles.

94.—March 20th; 1.1.13 p.m., Stations, 71, 72, 73, 64, 74, 75, 82, 83, 81, 80, 79, 78, 77, 92, 91, 90, 89, 87, 86, 85, 84, 101, 102, 103, 104, 105, 106, 107, 108, 109, 76, 123, 126, 121, 127, 129, 142, 141, 128, 140, 134, 133, 131, 113, 122, 94, 93, 120, 95, 119, 117, 115, 114, 116, 112, 110, 111, 97, 96, 118, 98, 99, 100; 22,860, square miles.

95.—March 20th, 1.57.0. p.m., Station, between 112 and 113; 98 square miles.

96.—March 20th, 2.21.48 p.m., Stations, 114, 115, 116, 117, 130, 100; 1,571 square miles.

97.—March 20th, about 4.0.0 p.m., Station, 96; 149 square miles.

98.—March 20th, 4.10.0 p.m., Station, 140; 173 square miles.

99.—March 20th, 11.20.0 p.m., Station, 141; 411 square miles.

100.—March 21st, 9.48.46 a.m., Station 124; 124 square miles.

101.—March 22nd, 11.25.0 a.m., Station 115; 368 square miles.

102.—March 23rd, 2.31.28 a.m., Station, 100; 71 square miles.
103.—March 23rd, 5.54.0 a.m., Station, 4; 149 square miles.
104.—March 24th, after 2.0.0 a.m., Station, 100; 71 square miles.
105.—March 24th, 11.50.0 p.m., Station, 4; 149 square miles.
106.—March 25th, 9.40.0 a.m., Stations, 23, 24, 25, 26; 1,737 square miles.
107.—March 26th, 1.0.0 p.m., Station, 89; 124 square miles.
108.—March 27th, 2.27.35 p.m., Stations, 100, 101, 103, 105; 422 square miles.
109.—March 28th, 1.7.0 a.m., Station, 100; 71 square miles.
110.—March 30th, 9.25.0 p.m., Stations, 204, 203, 201, 194, 195, 196, 197, 198, 200, 199; 4,714 square miles.
111.—March 30th, 9.35.0 p.m., Station, 221; 149 square miles.
112.—March 31st, 7.55.0 a.m., Station, 170; 149 square miles.
113.—March 31st, 10.15.0 p.m., Station, 216; 173 square miles.

APRIL.

114.—April 1st, 4.48.20 p.m., Station, 22; 398 square miles.
115.—April 1st, 5.55.0 p.m., Station, 23; 620 square miles.
116.—April 2nd, 3.50.0 a.m., Station, 125; 422 square miles.
117.—April 2nd, 5.30.0 a.m., Station, 202; 368 square miles.
118.—April 2nd, 8.25.0 a.m., Station, 181; 471 square miles.
119.—April 6th, 9.40.0 p.m., Station, 140; 349 square miles.
120.—April 7th, after 2.0.0 a.m., Station, 100; 71 square miles.
121.—April 8th, 8.10.0 a.m., Station, 81; 744 square miles.
122.—April 10th, 7.35.45 p.m., Station, 40; 344 square miles.
123.—April 10th, 8.18.0 p.m., Station, 87; 173 square miles.
124.—April 12th, 10.17.35 a.m., Station, 81; 744 square miles.
125.—April 17th, 11.10.0 p.m., Station, 41; 493 square miles.
126.—April 18th, 7.5.0 a.m., Station, 41; 493 square miles.
127.—April 18th, 7.5.0 p.m., Station, 107; 249 square miles.
128.—April 19th, 3.10.5 p.m., Station, 218; 220 square miles.
129.—April 21st, 3.45.0 p.m., Station, 4; 344 square miles.
130.—April 22nd, 2.9.45 a.m., Station, 81; 249 square miles.
131.—April 22nd, 4.30.0 a.m., Station, 181; 249 square miles.
132.—April 22nd, 3.44.0 p.m., Station, 84; 124 square miles.
133.—April 22nd, 4.30.0 p.m., Stations, 80.81; 993 square miles.
134.—April 23rd, 11.52.24 a.m., Station, 100; 71 square miles.
135.—April 23rd, about 0.0.0 p.m., Station, 79; 371 square miles.
136.—April 23rd, 7.41.0 p.m., Station, 89; 249 square miles.

137.—April 24th, 1.30.0 p.m., Stations, 67, 69, 70, 71, 72, 82, 83, 81, 80, 84, 88, 89, 90, 87, 86, 85, 102, 101, 103, 104, 105, 106, 107, 108; 6,591 square miles.

138.—April 24th, 2.30.0 p.m., Stations, 54, 66, 68, 67, 69, 71; 2,858 square miles.

139.—April 24th, 2.55.0 p.m., Stations, 84, 86, 87; 399 square miles.

140.—April 24th, 6.25.0 p.m., Station, 107; 322 square miles.

141.—April 24th, 11.26.0 p.m., Station, 167; 620 square miles.

142.—April 25th, about 6.0.0 a.m., Station, 71; 89 square miles.

143.—April 25th, 7.1.53 a.m, Stations, 54, 68, 82, 81, 83, 84, 85, 86, 87, 88, 89, 90, 91, 98, 99, 100, 101, 102, 103, 104, 105; 4,007 square miles.

144.—April 25th, 8.25.0 a.m., Station, 87; 72 square miles.

145.—April 25th, 9.10.0 a.m., Stations, 84, 85, 86; 149 square miles.

146.—April 25th, 9.15.0 a.m., Station, 142; 620 square miles.

147.—April 25th, 1.0.0 p.m., Station, 100; 124 square miles.

148.—April 26th, 3.30.0 p.m., Stations, 167, 168, 213; 1,418 square miles.

149.—April 26th, 4.35.0 a.m., Station, 202; 249 square miles.

150.—April 28th, 10.0.0 a.m., Stations, 166, 168, 167, 169, 172, 170, 212, 213; 2,041 square miles.

MAY.

151.—May 1st, 2.30.0 a.m., Stations, 89, 90, 91, 98, 99, 100, 101, 102, 107; 890 square miles.

152.—May 1st, 2.43.5 a.m., Stations, 169, 170; 250 square miles.

153.—May 1st, 8.20.0 p.m., Station, 23; 844 square miles.

154.—May 3rd, 3.30.0 a.m., Stations, 170, 169; 720 square miles.

155.—May 3rd, 10.15.0 p.m., Station, 107; 249 square miles.

156.—May 4th, 1.05.0 p.m., Station, 23; 720 square miles.

157.—May 4th, 5.30.0 p.m., Station, 23; 720 square miles.

158.—May 5th, 6.13.0 p.m. Stations, 204, 205; 422 square miles.

159.—May 6th, 8.45.30 a.m, Station, 49; 344 square miles.

160.—May 7th, 9.4.0 a.m., Stations, 48, 49, 50, 47, 51, 52, 53, 54, 68, 55, 66, 67, 69, 65, 63, 64, 72, 71, 70, 73, 75, 74, 82, 83, 84, 85, 86, 87, 81, 80, 88, 89, 90, 79, 78, 77, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 110, 111, 112, 116, 118, 119, 120; 19,104 square miles.

161.—May 7th, 10.54.0 a.m., Station, 48; 84 square miles.

162.—May 7th, 1.30.0 p.m., Station, 78; 344 square miles.

163.—May 8th, 3.30.0 a.m., Stations, 58, 59, 60, 61; 2084 square miles.

164.—May 8th, 4.0.0 a.m., Stations, 60, 61, 58, 59; 1,488 square miles.
165.—May 8th, 1.56.0 p.m., Stations, 167, 168; 571 square miles.
166.—May 8th, 9.19.0 p.m., Station, 244; 124 square miles.
167.—May 8th, 11.25.0 a.m., Station 4; 249 square miles.
168.—May 9th, 2.55.0 p.m., Station, 85; 251 square miles.
169.—May 9th, about 2.0.0 p.m., Station 166; 125 square miles.
170.—May 12th, 4.0.0 p.m., Stations, 187, 188; 917 square miles.
171.—May 13th, 5.32.0 p.m, Station, 23; 720 square miles.
172.—May 13th, 7.25.0 p.m., Station, 23; 720 square miles.
173.—May 13th, 8.50.0 p.m., Station, 51; 249 square miles.
174.—May 14th, 4.35.0 a.m., Station, 23; 720 square miles.
175.—May 14th, 5.3.0 a.m., Station, 23; 720 square miles.
176.—May 14th, 10.30.0 p.m., Stations, 70, 71, 82, 83, 84, 86; 2,137 square miles.
177.—May 15th, 2.30.0 a.m., Station, 200, 199, 205, 206, 207, 208; 2,233 square miles.
178.—May 15th, 3.30.0 a.m., Stations, 229, 231; 844 square miles.
179.—May 15th, about 2.0.0 p.m., Stations, 78, 79, 90, 91, 92; 791 square miles.
180.—May 15th, 9.40.0 p.m., Station, 183; 344 square miles.
181.—May 16th, 1.30.0 a.m., Station, 184; 249 square miles.
182.—May 16th, 7.30.0 a.m., Station, 184; 344 square miles.
183.—May 16th, 1.22.0 p.m., Station, 79; 273 square miles.
184.—May 16th, about 8.0.0 p.m., Station, 128; 893 square miles.
185.—May 16th, 2.35.0 p.m., Station, 184; 298 square miles.
186.—May 17th, 7.0.0 a.m., Station, 53; 249 square miles.
187.—May 18th, 11.43.0 p.m., Station, 128; 993 square miles.
188.—May 19th, 1.35.0 a.m., Station, 87; 273 square miles.
189.—May 19th, 2.50.0 a.m., Stations, 81, 100; 566 square miles.
190.—May 19th, about 3.0.0 a.m., Station, 205; 71 square miles.
191.—May 19th, 4.10.0 p.m., Station, 50; 124 square miles.
192.—May 19th, 6.3.0 p.m., Station, 50; 124 square miles.
193.—May 19th, 11.53.32 p.m., Station, 81; 344 square miles.
194.—May 20th, 3.0.0 a.m., Station, 167; 720 square miles.
195.—May 21st, 5.15.0 a.m., Station, 79; 620 square miles.
196.—May 21st, 6.26.55 a.m., Station, 81; 368 square miles.
197.—May 21st, 1.40.0 p.m., Station, 244; 124 square miles.
198.—May 25th, 3.4.48 a.m., Station, 170; 124 square miles.

199.—May 25th, 6.12.30 a.m., Stations, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 141, 142, 140, 137, 138, 139, 154, 155, 156, 157, 158, 159, 160, 161, 164, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 184, 185; 12,039 square miles.

200.—May 25th, 7.35.0 a.m., Station, 175; 78 square miles.

201.—May 29th, 5.30.0 a.m., Stations, 151, 150, 153, 154, 155, 157, 158, 159, 160, 161, 148; 2,755 square miles.

JUNE.

202.—June 1st, about 2.0.0 a.m., Stations, 189, 190, 194, 195, 196, 197, 198, 199, 200, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227; 8,418 square miles.

203.—June 4th, 0.40.0 p.m., Station, 50; 24 square miles.

204.—June 6th, about 4.0.0 p.m., Stations, 242, 238, 236, 237, 225, 227, 235, 240; 2,977 square miles.

205.—June 7th, 8.0.0 p.m., Stations, 43, 47, 48, 49, 50, 51, 52, 53, 54, 68; 2,828 square miles.

206.—June 7th, 11.34.18 p.m., Stations, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 98, 100, 101, 102; 4,590 square miles.

207.—June 8th, 8.20.0 a.m., Station, 33; 190 square miles.

208.—June 8th, 1.50.0 a.m., Stations, 4, 29, 33; 1,274 square miles.

209.—June 10th, 10.30.0 p.m., Station, 23; 720 square miles.

210.—June 11th, 9.30.0 a.m., Stations, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 68; 21,850 square miles.

211.—June 11th, 9.20.5 a.m., Stations, 79, 100, 118; 244 square miles.

212.—June 12th, 7.41.10 a.m., Station, 22; 249 square miles.

213.—June 13th, 11.0.0 a.m., Stations, 231, 233, 234, 246; 1,203 square miles.

214.—June 14th, 9.3.0 p.m., Station, 50; 173 square miles.

215.—June 14th, 9.33.21 p.m., Stations, 169, 170; 250 square miles.

216.—June 14th, 11.40.0 p.m., Station, 74; 368 square miles.

217.—June 15th, 1.41.41 a.m., Stations, 60, 64, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 130; 17,986 square miles.

218.—June 15th, 0.45.0 a.m., Station, 23; 238 square miles.

219.—June 15th, 4.0.0 a.m., Station, 77; 220 square miles.

220.—June 15th, 8.40.0 a.m., Station, 100; 71 square miles.

221.—June 15th, 9.20.0 p.m., Stations, 23, 24, 32; 1,715 square miles.

222.—June 15th, 12.0.0 p.m., Station, 17; 368 square miles.

223.—June 18th, 2.30.0 a.m., Stations, 81, 87, 88, 89, 90, 102; 596 square miles.

224.—June 18th, 1.36.45 p.m., Stations, 43, 47, 49, 50, 51, 52, 46, 53, 54, 68, 55, 66, 67, 65, 63, 70, 71, 72, 64, 73, 74, 82, 83, 84, 80, 81, 85, 86, 87, 88, 89, 90, 78, 79, 92, 91, 97, 96, 98, 99, 100, 101, 102, 103, 104, 105, 111; 15,571 square miles.

225.—June 19th, 0.30.0 a.m., Stations, 79, 82; 399 square miles.

226.—June 19th, 1.0.0 a.m., Station, 4; 71 square miles.

227.—June 19th, after 9.0.0 a.m., Stations, 49, 50; 220 square miles.

228.—June 19th, 11.10.0 p.m., Station, 23; 720 square miles.

229.—June 19th, 11.15.0 p.m., Station, 23; 720 square miles.

230.—June 21st, 2.12.0 a.m., Station, 23; 720 square miles.

231.—June 24th, 7.35.0 a.m., Stations, 79, 87; 471 square miles.

232.—June 24th, 7.0.0 p.m., Station, 179; 173 square miles.

233.—June 24th, 10.56.30 p.m., Station, 247; 71 square miles.

234.—June 26th, 9.45.0 a.m., Station, 50; 71 square miles.

235.—June 26th, 10.0.0 a.m., Stations, 150, 151, 153, 154, 155, 158; 1,363 square miles.

236.—June 26th, 10.10.0 p.m., Station, 117; 173 square miles.

237.—June 27th, 4.0.0 a.m., Station, 203; 273 square miles.

238.—June 27th, 8.52.0 a.m., Station, 4; 124 square miles.

239.—June 27th, 10.45.30 a.m., Station, 154; 71 square miles.

240.—June 27th, 1.40.0 p.m., Stations, 82, 83, 84; 471 square miles.

241.—June 28, 2.22.18 a.m., Stations, 123, 121, 120, 95, 118, 119, 117, 130, 115, 114, 113, 116, 112, 110, 111, 99, 100, 96; 5,090 square miles.

242.—June 30th, 1.0.0 a.m., Station, 169; 220 square miles.

243.—June 30th, 7.7.15 p.m., Station 151; 249 square miles.

244.—June 30th, 10.30.0 p.m., Stations, 31, 38, 39, 34, 40, 41, 42, 37, 43, 47, 48, 49, 50, 51, 52, 53, 54, 68; 822 square miles.

JULY.

245.—July 1st, 3.2.0 a.m., Station, 4; 71 square miles.

246.—July 1st, 0.10.0 p.m., Stations, 123, 124; 993 square miles.

247.—July 1st, 7.0.0 p.m., Stations, 184, 181; 993 square miles.

248.—July 2nd, 2.57.0 p.m., Station, 23; 493 square miles.

249.—July 3rd, 7.32.15 a.m., Station, 22; 249 square miles.

250.—July 3rd, 2.15.0 p.m., Station, 184; 71 square miles.

251.—July 5th, 2.30.0 a.m., Station, 4; 71 square miles.

252.—July 5th, 2.27.0 p.m., Stations, 226, 228; 322 square miles.

253.—July 6th, 2.40.0 a.m., Station, 120; 471 square miles.

254.—July 8th, 11.27.0 a.m., Station, 244; 249 square miles.

255.—July 9th, 3.14.0 a.m., Stations, 13, 14; 471 square miles.

256.—July 10th, 3.10.0 a.m., Stations, 13, 14, 16, 17, 18, 19, 20, 22, 23, 24, 26, 27, 32, 30, 31; 13,475 square miles.

257.—July 10th, 1.32.0 a.m., Station, 22; 131 square miles.

258.—July 11th, after 1.0.0 p.m., Stations, 74, 78, 79, 80, 81, 88, 90, 89; 1,810 square miles.

259.—July 13th, 5.55.0 a.m., Station, 181; 71 square miles.

260.—July 14th, 8.17.0 p.m., Station, 70; 124 square miles.

261.—July 15th, 4.45.54 p.m., Stations, 99, 111; 124 square miles.

262.—July 16th, 6.37.15 a.m., Station, 81; 249 square miles.

263.—July 21st, after 2.0.0 a.m., Stations, 14, 17, 18, 20, 22, 23; 5,458 square miles.

264.—July 21st, about 6.0.0 a.m., Stations, 78, 79, 80, 88, 87, 89, 90, 91, 92, 98, 102; 1,935 square miles.

265.—July 22nd, 2.7.0 a.m., Station, 4; 71 square miles.

266.—July 22nd, 9.22.56 a.m., Station, 81; 368 square miles.

267.—July 24th, 1.50.0 a.m., Stations, 232, 233, 247; 344 square miles.

268.—July 24th, about 3.0.0 a.m., Stations, 231, 233; 493 square miles.

269.—July 24th, 8.45.28 a.m., Stations, 147, 148; 71 square miles.

270.—July 24th, 6.1.5 p.m., Stations, 147, 148; 71 square miles.

271.—July 28th, 8.50.45 a.m., Station, 170; 124 square miles.

272.—July 29th, 5.21.53 a.m., Stations, 4, 6, 5, 8, 7, 9, 10, 15, 16, 13, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 49; 23,344 square miles.

273.—July 29th, 6.14.5 p.m., Stations, 81, 87, 88, 89; 869 square miles.

274.—July 29th, 6.30.2 p.m., Station, 19; 137 square miles.

275.—July 29th, 8.3.0.0 p.m., Stations, 81, 87, 88, 89; 744 square miles.

276.—July 30th, 11.42.0 p.m., Station, 88; 124 square miles.

AUGUST.

277.—August 1st, 3.0.0 a.m., Station, 75; 132 squure miles.

278.—August 2nd, 2.30.0 a.m., Station, 78; 95 square miles.

279.—August 2nd, 11.20.0 a.m., Station, 4; 232 square miles.

280.—August 3rd, 3.47.0 p.m., Station, 78; 37 square miles.

281.—August 7th, about 0.0.0 a.m., Station, 68; 78 square miles.

282.—August 8th, 8.4.0 a.m., Stations, 169, 170; 422 square miles.

383.—August 8th, 11.30.0. p.m., Stations, 43, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56; 3,555 square miles.

284.—August 11th, after 5.0.0 a.m., Stations, 81, 85, 86, 87, 88, 89, 102; 1,005 square miles.

285.—August 11th, about 8.0.0 a.m., Stations, 195, 196, 197, 198, 201, 194; 1,394 square miles.

286.—August 12th, 2.30.0 a.m., Stations, 81, 84, 86, 87, 88; 422 square miles.

287.—August 13th, 9.32.0 a.m., Stations, 227, 228, 229, 230, 231, 232, 233, 234, 246, 247; 3,763 square miles.

288.—August 16th, 10.20.0 p.m., Stations, 219, 220; 227 square miles.

289.—August 19th, 9.13.30 p.m., Stations, 170; 37 square miles.

290.—August 19th, 11.30.0 p.m., Station, 165; 196 square miles.

291.—August 20th, 3.45.0 a.m., Stations, 135, 136, 137, 138, 139, 140, 156, 155, 153, 150, 154, 159, 153, 157, 149, 161, 160, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 148, 181, 184, 185; 9,401 square miles.

292.—August 21st, 11.30.00 p.m., Stations, 140, 137; 612 square miles.

293.—August 22nd, after 2.0.0 a.m., Stations, 141, 142, 140, 137, 139, 138; 1,588 square miles.

294.—August 24th, 11.55.0 p.m., Station, 5; 488 square miles.

295.—August 24th, 1.31.0 a.m., Station 8; 72 square miles.

296.—August 25th, 2.30.0 a.m., Stations, 5, 8, 7, 9, 16, 23; 2,553 square miles.

297.—August 25th, 1.35.0 p.m., Station, 102; 66 square miles.

298.—August 26th, 5.2.30 a.m., Station, 100; 83 square miles.

299.—August 26th, after 6.0.0 p.m., Stations, 235, 236, 237, 245; 1,459 square miles.

300.—August 26th, after 8.0.0 p.m., Stations 235, 237, 238, 240, 242, 245; 1,620 square miles.

301.—August 28th, 9.37.28 p.m., Station, 100; 66 square miles.

302.—August 29th, about 1.00.00 a.m., Stations, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 211, 212, 213, 214, 215, 189, 190; 5,858 square miles.

303.—August 30th, about 10.0.0 p.m., Stations, 187, 192, 191; 583 square miles.

304.—August 31st, about 4.0.0 a.m., Station, 107; 29 square miles.

305.—August 31st, 5.23.55 a.m., Station, 100; 29 square miles.

SEPTEMBER.

306.—September 2nd, 8.31.22 a.m., Stations, 73, 74, 78, 79, 80, 81, 84, 85, 86, 87, 88, 89, 90, 91, 92, 98, 100, 101, 102, 105, 119; 5,030 square miles.

307.—September 2nd, 9.50.0 a.m., Station, 89; 72 square miles.

308.—September 5th, 8.40.0 a.m., Station, 100; 66 square miles.

309.—September 5th, about 8.0.0 p.m., Stations, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 16, 17, 20, 22, 23, 24, 25, 26, 27, 28; 18,575 square miles.

310.—September 5th, 9.11.0 p.m., Station, 1; 130 square miles.

311.—September 5th, 11.10.0 p.m., Stations, 1, 2, 3, 4, 5, 6, 8; 4,895 square miles.

312.—September 6th, 2.21.0 a.m., Stations, 26, 27; 714 square miles.

313.—September 6th, 2.30.21 a.m., Station, 1, 2; 65 square miles.

314.—September 6th, 7.35.0 a.m., Station, 31; 649 square miles.

315.—September 6th, 8.10.0 a.m., Station, 8; 429 square miles.

316.—September 8th, 8.40.0 a.m., Station, 78; 132 square miles.

317.—September 8th, 10.5.0 p.m., Station, 6; 135 square miles.

318.—September 8th, 11.20.0 p.m., Stations, 3, 4, 5, 6, 7, 8, 9, 10, 16, 17, 20, 22, 23, 24, 26, 27, 31, 32; 12,761 square miles.

319.—September 9th, about 9.0.0 p.m., Stations, 82, 83, 81, 84, 86, 87, 88, 89, 90, 102, 103, 80, 73, 74, 79; 3,340 square miles.

320.—September 10th, 11.15.0 a.m., Stations, 243, 244; 100 square miles.

321.—September 10th, 8.19.6 p.m., Station, 100; 29 square miles.

322.—September 11th, 1.24.30 a.m., Station, 100; 90 square miles.

323.—September 12th, 3.5.0 a.m., Station, 23; 471 square miles.

324.—September 14th, 1.45.0 p.m., Station, 100; 29 square miles.

325.—September 14th, 6.50.0 p.m., Station, 164; 83 square miles.

326.—September 14th, 9.40.0 p.m., Station, 143; 95 square miles.

327.—September 15th, 5.48.40 p.m., Station, 170; 60 square miles.

328.—September 15th, before 7.0.0 p.m., Stations, 96, 117, 118; 690 square miles.

329.—September 16th, 3.55.0 p.m., Station, 73; 26 square miles.

330.—September 18th, 0.33.23 p.m., Station, 170; 132 square miles.

331.—September 20th, 1.13.50 a.m., Station, 100; 29 square miles.

332.—September 22nd, 2.29.43 a.m., Station, 100; 30 square miles.

333.—September 22nd, about 3.0.0 a.m., Stations, 113, 114, 118, 119, 120, 122; 887 square miles.

334.—September 22nd, 0.11.0 p.m., Station, 246; 59 square miles.

335.—September 23rd, about 7.0.0 a.m., Stations, 227, 228, 230; 71 square miles.

336.—September 25th, 2.10.0 a.m., Station, 3; 876 square miles.

337.—September 25th, 9.25.0 a.m., Station, 119; 161 square miles.

338.—September 25th, about 11.0.0 a.m., Station, 119; 66 square miles.

339.—September 26th, 2.39.0 a.m., Stations, 4, 5, 6; 1,430 square miles.

340.—September 26th, 11.35.0 a.m., Station, 113; 63 square miles.

341.—September 26th, 0.2.45 p.m., Stations, 107, 108, 109, 101, 102, 89, 90, 91, 92, 98, 100, 99, 110, 111, 96, 97, 93, 78, 95, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 150, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 149, 162, 163, 164, 177; 16,713 square miles.

342.—September 27th, about 6.0.0 p.m., Stations, 5, 8; 1,132 square miles.

343.—September 27th, 9.20.0 p.m., Station, 164; 66 square miles.

344.—September 28th, 5.25.0 a.m., Stations, 162, 163, 164, 165, 173, 174, 175, 161, 160, 149, 157, 158, 159, 150, 154, 153, 152, 153, 155, 156, 141, 140, 139, 138, 127, 142, 127, 128, 136, 135, 109, 89, 90, 91, 92, 96, 98, 100, 99, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 126, 129, 130, 131, 132, 133, 134; 15,578 square miles.

345.—September 28th, 6.1.0 a.m., Station, 122; 88 square miles.

346.—September 28th, 10.34.0 a.m., Station, 100; 63 square miles.

347.—September 28th, about 4.0.0 p.m., Stations, 246, 247; 132 square miles.

348.—September 29th, 8.39.9 a.m., Station 800; 30 square miles.

349.—September 29th, about 9.0.0 a.m., Stations, 119, 114; 232 square miles.

350.—September 29th, 6.20.0 p.m., Station 119; 95 square miles.

OCTOBER.

351.—October 1st, 7.30.0 a.m., Station, 247; 190 square miles.

352.—October 1st, 1.8.57 p.m., Stations, 73, 74, 75, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108; 7,579 square miles.

353.—October 2nd, after 7.0.0 p.m., Stations, 31, 38, 39, 40, 41, 42, 43, 47, 48, 49, 50, 51. 52, 53, 54; 7,662 square miles.

354.—October 3rd, 5.4.0 a.m., Station, 4; 173 square miles.

355.—October 5th, after 11.0.0 a.m,, Stations, 81, 84, 85, 86, 87, 88, 89, 102, 103, 104; 2,059 square miles.

356.—October 6th, 6.40.0 a.m., Station, 144; 100 square miles.

357.—October 7th, after 1.0.0 p.m., Stations, 73, 74, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 102, 103, 104; 4,226 square miles.

358.—October 7th, 7.35.0 a.m., Station, 100; 66 square miles.

359.—October 7th, 8.25.0 p.m., Stations, 1, 2, 3, 4, 5, 6, 8; 3,716 square miles.

360.—October 8th, 1.37.0 p.m., Station, 230; 1,599 square miles.

361.—October 9th, 7.53.0 p.m., Station, 100; 78 square miles.

392.—October 11th, 5.30.0 a.m., Station, 78, 79, 80, 81, 82, 83, 84, 85, 56, 87, 88, 89, 90, 91, 92, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108; 5,978 square miles.

363.—October 12th, 0.21.0 p.m., Station, 4; 178 square miles.

364.—October 12th, 9.10.0 p.m., Station, 168; 154 square miles.

365.—October 14th, about 9.0.0 a.m., Stations, 3, 4, 5; 1,525 square miles.

366.—October 15th, 1.40.0 a.m., Station, 41; 173 square miles.

367.—October 15th, before 9.0.0 a.m., Stations, 96, 98, 100, 99, 111, 112, 115, 116, 117, 118, 119, 95, 120, 121, 122, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165; 14,330 square miles.

368.—October 15th, 8.43.3 p.m., Stations, 87, 89, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110 111; 2,899 square miles.

369.—October 16th, 5.58.0 a.m., Station, 170; 154 square miles.

370.—October 17th, after 5.0.0 a.m., Stations, 206, 207; 590 square miles.

371.—October 17th, 1.55.0 p.m., Stations, 235, 237; 398 square miles.

372.—October 18th, 1.15.0 a.m., Station, 210'; 207, square miles.

373.—October 18th, before 10.0.0 a.m., Station, 140; 273 square miles.

374.—October 18th, about 0.0.0. p.m., Stations, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 102, 103, 104; 2,567 square miles.

375.—October 19th, after 9.0.0 a.m., Stations, 127, 143; 2,179 square miles.

376.—October 20th, 10.0.0 p.m., Station, 89; 190 square miles.

377.—October 21st, 0.10.0 a.m., Station, 4; 220 square miles.

378.—October 21st, after 1.0.0 a.m., Stations, 76, 77, 93, 94, 95, 96, 97, 98, 99, 100, 110, 111, 112, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134. 135, 136, 137, 138, 139, 140, 141, 142, 143, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 164, 174, 175, 177, 178, 185; 19,522 square miles.

379.—October 21st, 7.38.0 p.m., Stations, 229, 231, 232, 233, 234, 246, 247; 2.245 square miles.

380.—October 22nd, 2.13.0 p.m., Station, 119; 166 square miles.

381.—October 24th, after 5.0.0 a.m., Stations, 84, 85, 86, 87, 89, 99, 100, 101, 102, 103, 104, 105; 2,555 square miles.

382.—October 24th, 1.5.0 a.m., Station, 4; 173 square miles.

383.—October 26th, before 7.0.0 p.m., Stations, 81, 83; 2,647 square miles.

384.—October 26th, 10.41.0 p.m., Stations, 108, 109, 95, 96, 97, 91, 92, 98, 99, 100, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 130, 131, 132, 133, 141, 142, 153, 155; 6,798 square miles.

385.—October 27th, 1.30.0 a.m., Station, 158; 132 square miles.

386.—October 27th, 7.50.0 p.m., Station, 213; 173 square miles.

387.—October 28th, 10.12.0 p.m., Stations, 197, 198; 231 square miles.

388.—October 29th, 3.18.0 p.m., Station, 81; 207 square miles.

389.—October 30th, 8.30.0 p.m., Stations, 4, 5, 6, 7, 8, 9, 17, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 98, 100, 101, 102, 103, 105; 34,738 square miles.

390.—October 31st, 10.30.0 a.m., Station, 247; 120 square miles.

391.—October 31st, about 2.0.0 p.m., Station, 246; 83 square miles.

NOVEMBER.

392.—November 1st, 3.27.0 a.m., Stations, 4, 5, 7, 8; 1,557 square miles.

393.—November 1st, 5.20.0 a.m., Station, 5; 97 square miles.

394.—November 1st, 1.17.0 p.m., Station, 198, 199, 200, 205, 218, 219, 220, 221; 2,054 square miles.

395.—November 1st, 8.25.0 p.m., Station, 247; 83 square miles.

396.—November 1st, 8.33.0 p.m., Station, 247; 83 square miles.

397.—November 2nd, 3.11.0 a.m., Station, 31; 293 square miles.

398.—November 2nd, 0.20.0 p.m., Stations, 4, 5, 7, 8; 1,418 square miles.

399.—November 3rd, 10.50.0 p.m., Stations, 114, 115, 117, 119, 130; 1,194 square miles.

400.—November 3rd, 11.30.0 p.m., Station, 119; 104 square miles.

401.—November 4th, 5.30.0 a.m., Station, 290; 173 square miles.

402.—November 6th, 7.8.0 a.m., Station, 103; 195 square miles.

403.—November 6th, about 9.0.0 p.m., Stations 78, 79, 80, 81, 87, 88, 89, 90, 91, 92, 102, 103; 2,301 square miles.

404.— November 7th, 1.7.0 p.m., Station, 20; 195 square miles.

405.—November 7th, 7.16.0 p.m., Station, 4; 17 square miles.

406.—November 7th, 8.29.0 p.m., Station, 57; 95 square miles.

407.—November 7th, 8.55.0 p.m., Stations, 63, 64, 73, 80, 88; 293 square miles.

408.—November 7th, about 11.0.0 p.m., Stations, 63, 64; 322 square miles.

409.—November 8th, 11.5.0 a.m., Station, 81; 161 square miles.

410.—November 9th, 2.07.0 a.m., Station, 178; 29 square miles.

411.—November 10th, about 0.0.0 a.m., Stations, 233, 246, 247; 285 square miles.

412.—November 11th, 8.37.0 p.m., Station, 4; 83 square miles.

413.—November 11th, about 9.0.0 p.m., Stations, 100, 107, 108, 109; 715 square miles.

414.—November 12th, after 7.0.0 a.m., Stations, 198, 199, 200, 207, 208, 209; 1,261 square miles.

415.—November 12th, 1.10.0 p.m., Station, 85; 649 square miles.

416.—November 12th, about 8.0.0 p.m., Stations, 81, 85, 86, 87, 89, 102, 103; 1,166 square miles.

417.—November 12th, 9.7.15 p.m., Station, 170; 124 square miles.

418.—November 13th, 5.30.0 a.m., Station, 5; 249 square miles.

419.—November 13th, before 8.0.0 a.m., Stations, 78, 79, 80, 81, 87, 88, 89, 90, 102; 1,637 square miles.

420.—November 14th, 3.55.0 a.m., Station, 178; 29 square miles.

421.—November 14th, 2.0.0 p.m., Station, 123; 30 square miles.

422.—November 14th, 2.25.0 p.m., Station, 4; 124 square miles.

423.—November 16th, 9.9.0 a.m., Station, 81; 215 square miles.

424.—November 16th, 1.51.0 p.m., Stations, 98, 99, 100, 108; 227 square miles.

425.—November 18th, after 6.0.0 p.m., Stations, 71, 72, 81, 82, 83, 84; 1,525 square miles.

426.—November 18th, 8.7.0 p.m., Station, 7; 112 square miles.

427.—November 18th, 9.21.0 p.m., Station, 88; 65 square miles.

428.—November 18th, 9.55.0 p.m., Stations, 5, 6, 7, 8; 1,348 square miles.

429.—November 19th, 10.25.0 a.m., Station, 108; 95 square miles.

430.—November 19th, 11.31.0 a.m., Station, 91; 178 square miles.

431.—November 19th, 11.58.0 p.m., Station, 88; 95 square miles.

432.—November 20th, 0.10.0 a.m., Station, 81; 195 square miles.

433.—November 20th, about 8.0.0 p.m., Stations, 99, 100, 101, 105, 106, 107, 108; 1,037 square miles.

434.—November 21st, 2.18.0 a.m., Stations, 4, 5; 368 square miles.

435.—November 21st, 8.27.0 p.m., Station, 51; 98 square miles.

436.—November 23rd, 7.58.0 a.m., Station, 88; 95 square miles.

437.—November 23rd, 10.45.0 p.m., Station, 52; 95 square miles.

438.—November 24th, 1.14.0 a.m., Station, 102; 66 square miles.

439.—November 24th, 2.14.0 p.m., Station, 52; 95 square miles.

440.—November 27th, midnight, Stations, 168, 167; 161 square miles.

441.—November 29th, about 11.0.0 a.m., Stations, 238, 239, 240, 241, 242; 1,278 square miles.

442.—November 29th, after 10.0.0 p.m., Station, 155; 161 square miles.

DECEMBER.

443.—December 1st, 2.9.0 p.m., Station, 4, 5, 6, 7, 8, 9; 2,757 square miles.

444.—December 1st, 10.45.0 p.m., Stations, 72; 195 square miles.

445.—December 3rd, after 6 0.0 a.m., Stations, 87, 88, 89, 90, 91, 92, 98; 99, 100, 102, 101, 103, 111; 1,918 square miles.

446.—December 4th, 7.17.0 p.m., Stations, 23, 24, 26, 27, 30, 31, 32, 38, 40; 4,858 square miles.

447.—December 5th, 7.20.0 a.m., Station, 41; 131 square miles.

448.—December 5th, 7.20.0 a.m., Station, 71; 196 square miles.

449.—December 6th, 6.30.0 a.m., Stations, 51; 161 square miles.

450.—December 6th, before 5.0.0 p.m., Stations, 79, 80, 81, 87, 88, 89, 90, 91, 92, 102; 1,518 square miles.

451.—December 6th, 8.13.0 p.m., Stations, 99, 100, 98, 101, 103, 105; 971 square miles.

452.—December 7th, 6.30.0 a.m., Station, 214; 195 square miles.

453.—December 7th, about 1.0.0 p.m., Stations, 47, 49, 51, 52, 53, 54, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 117, 118, 119, 106, 107, 108, 109; 17,217 square miles.

454.—December 7th, 2.53.0 p.m., Station, 40; 322, square miles.

455.—December 7th, before 8.0.0 p.m., Stations, 98, 99, 100, 101, 103, 104, 105, 106, 107, 108; 226, square miles.

456.—December 7th, 8.8.0 p.m., Stations 79, 80; 89 square miles.

457.—December 8th, 3.0.0 a.m., Station, 54; 132 square miles.

458.—December 11th, 2.58.0 a.m., Station 246; 54 square miles.

459.—December 11th, after 10.0.0 a.m., Station, 207; 66 square miles.

460.—December 13th, about 3.30.0 a.m., Stations, 127, 128, 129, 154; 1,815 square miles.

461.—December 13th, after 4.0.0 a.m., Stations, 128, 134, 137, 142; 1,249 square miles.

462.—December 13th, 10.5.0 a.m., Station, 142; 132 square miles.

463.—December 14th, 7.11.0 a.m., Station, 127; 261 square miles.

464.—December 16th, 10.6.0 p.m., Station, 107; 132 square miles.

465.—December 17th, 10.20.0 p.m., Stations, 48, 88; 90 square miles.

466.—December 18th, about 0.30.0 a.m., Stations, 81, 87, 88; 649 square miles.

467.—December 19th, 3.30.0 a.m., Stations, 81, 82, 83, 84, 85, 86, 87, 88, 89, 102; 1,488 square miles.

468.—December 19th, 6.26.40 p.m., Stations, 69, 70, 71, 72, 73, 74, 75, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107 108; 9,827 square miles.

469.—December 19th, about 8.0.0 p.m., Station, 86; 92 square miles.

470.—December 19th, 11.46.0 p.m., Station, 186; 95 square miles.

471.—December 21st, 0.20.0 a.m., Station, 79; 161 square miles.

472.—December 22nd, after 11.0.0 a.m., Stations, 165, 166 167, 168, 169, 170, 171, 172, 173, 213, 189, 190, 193; 2,852 square miles.

473.—December 22nd, 1.21.0 p.m., Stations, 178, 175; 107 square miles.

474.—December 24th, 6.30.0 a.m., Station 146; 142 square miles.

475.—December 25th, 2.30.0 a.m., Stations, 46, 47, 49, 51, 52, 53, 54, 66, 67, 68, 69, 70, 71; 5,056 square miles.

476.—December 25th, 9.38.0 a.m., Station, 142; 132 square miles.

477.—December 26th, after 3.0.0 p.m., Stations, 146, 147, 179, 180; 781 square miles.

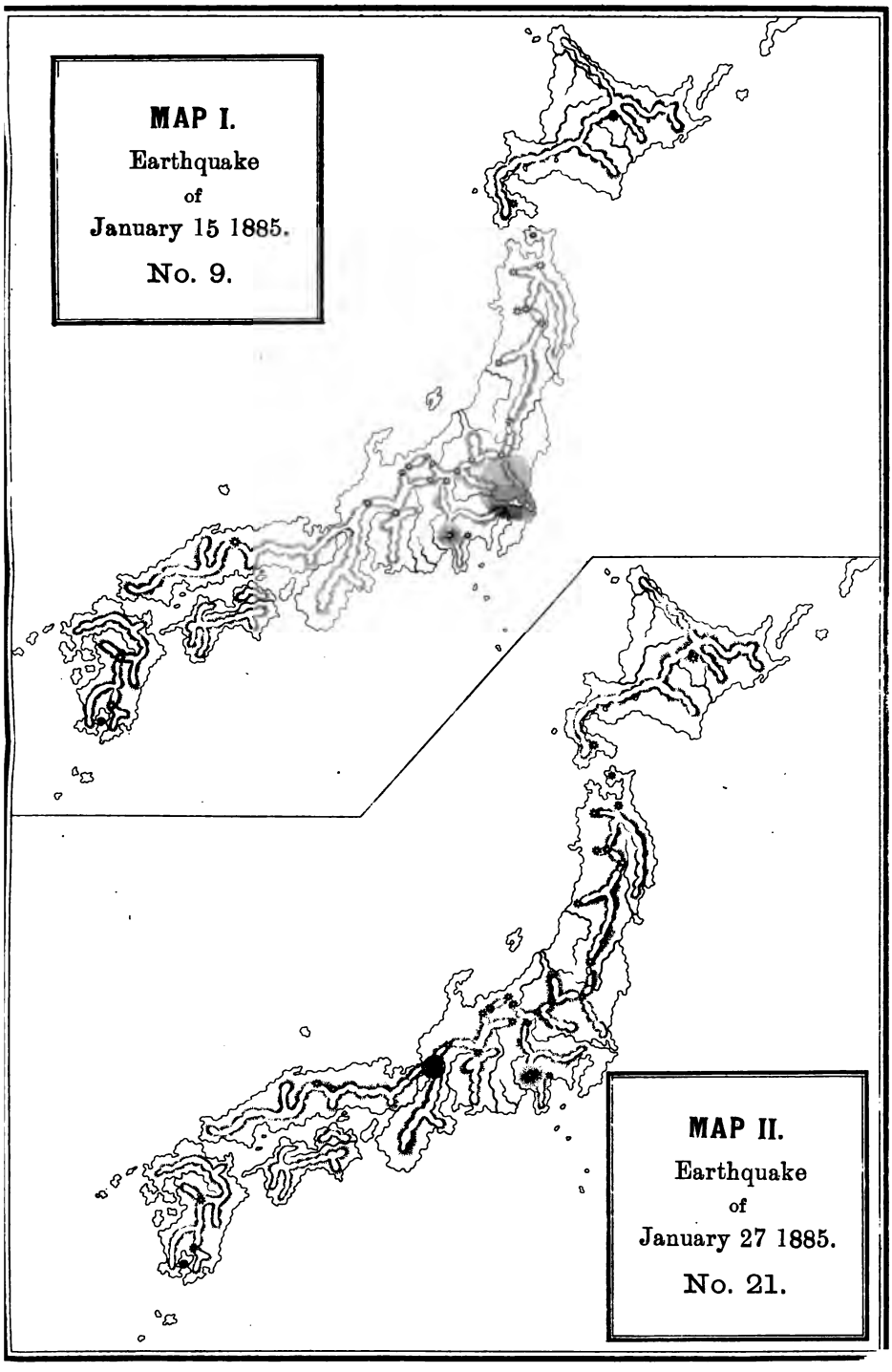
478.—December 28th, 10.6.30 p.m., Stations, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 90, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111 112, 113, 114, 115, 116, 117, 118, 119, 120, 122; 13,261 square miles.

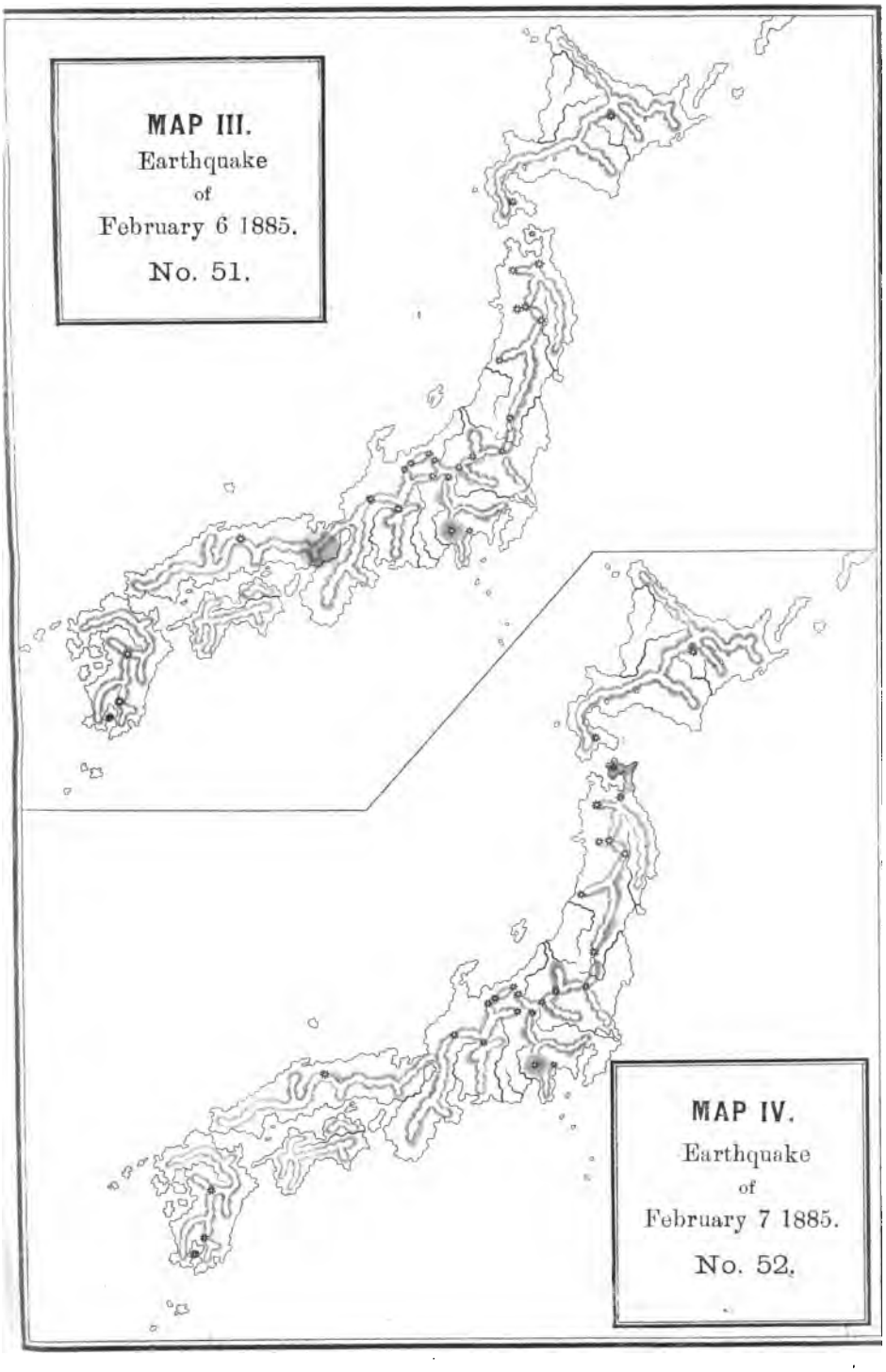
479.—December 28th, 11.25.0 p.m., Station, 73; 72 square miles.

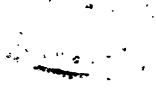
480.—December31st, 6.30.0 p.m., Station, 102; 95 square miles.

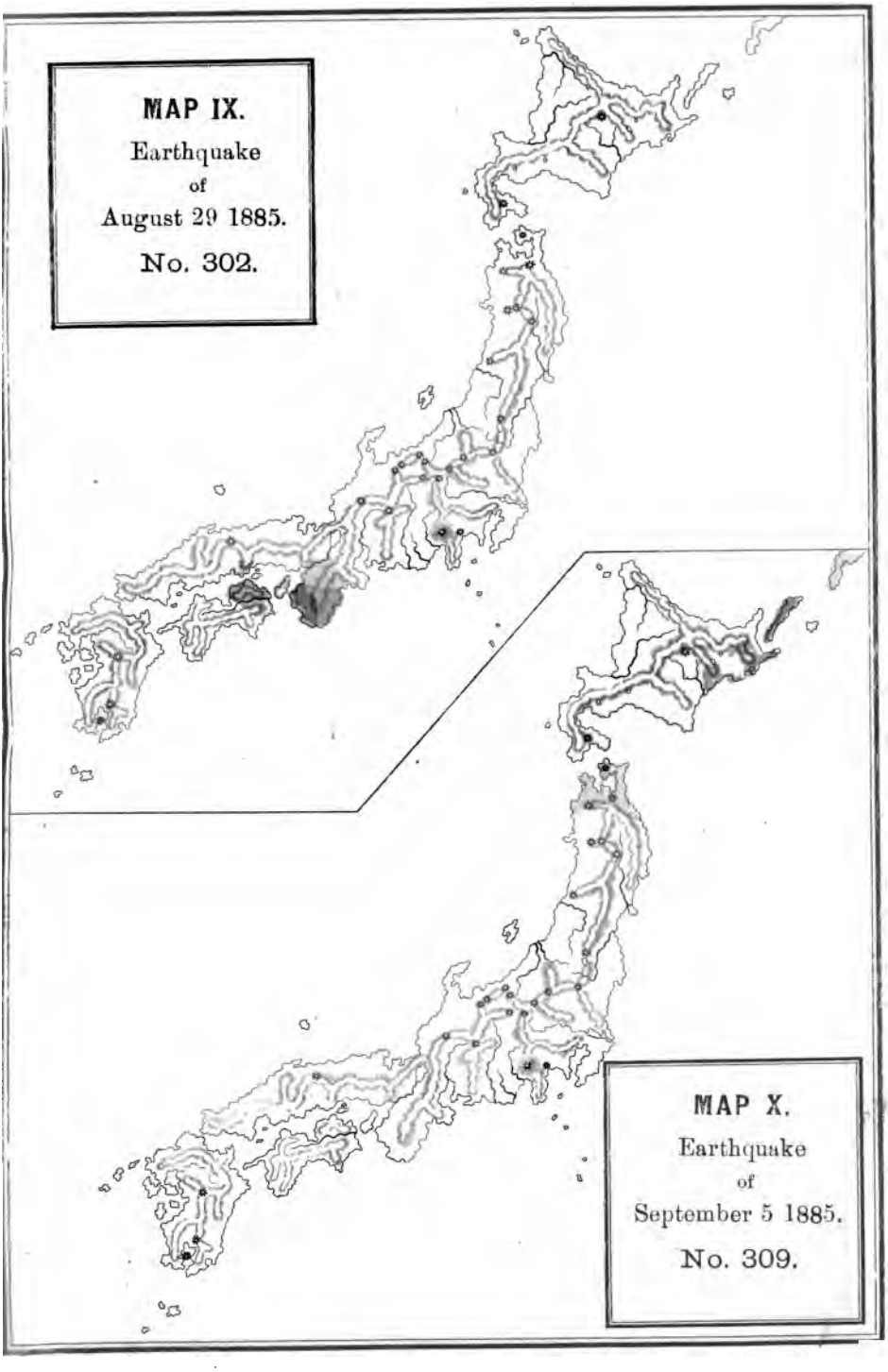
481.—December 31st, 3.27.0 p.m., Station, 81; 95 square miles.

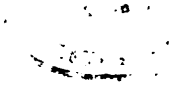
482.—December 31st, 9.56.0 p.m., Station, 81; 95 square miles.

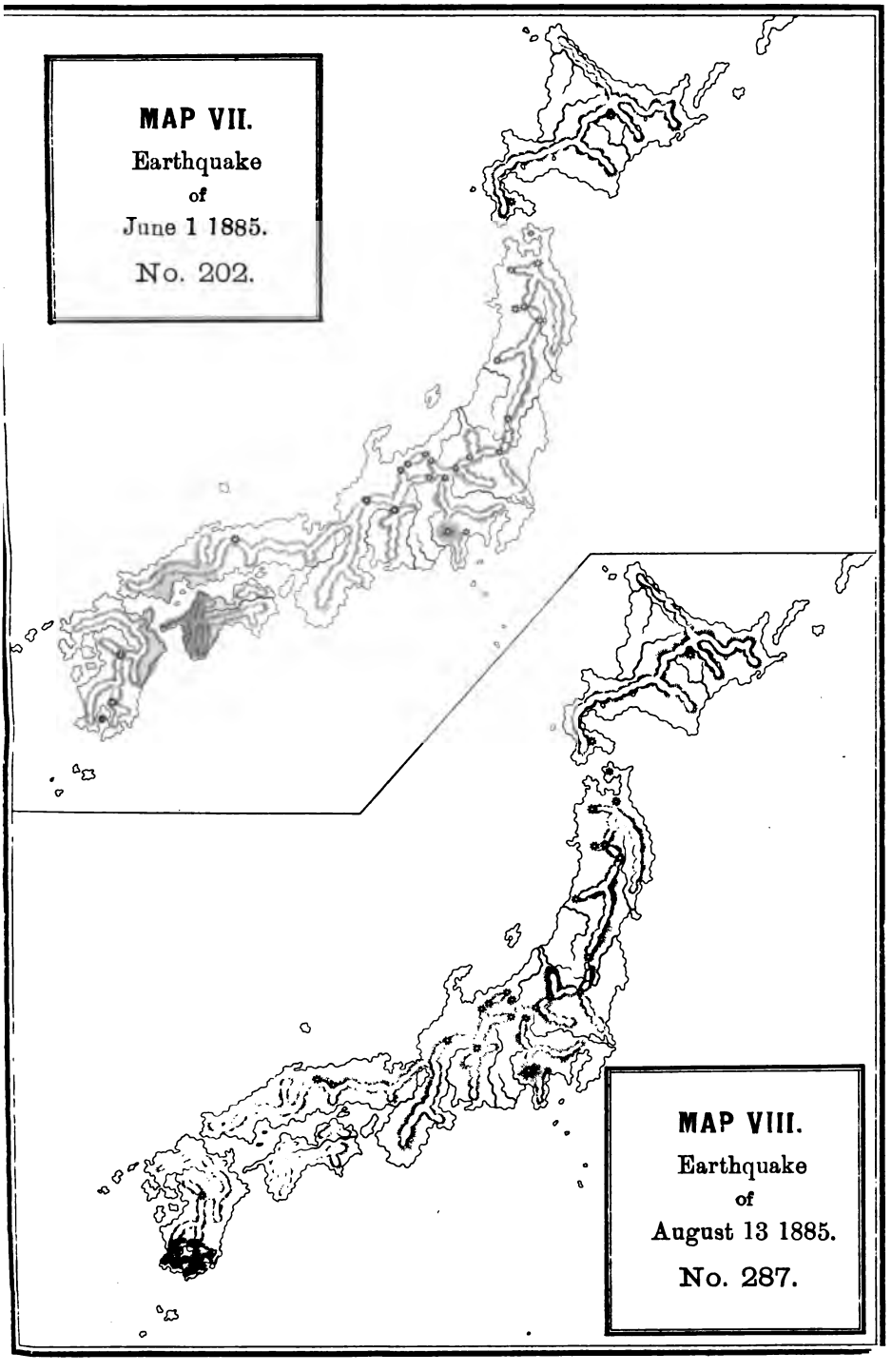

MAP I.
Earthquake
of
January 15 1885.
No. 9.
MAP II.
Earthquake
of
January 27 1885.
No. 21.

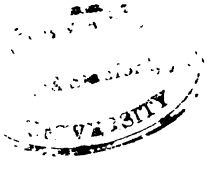

MAP III.
Earthquake
of
February 6 1885.
No. 51.
MAP IV.
Earthquake
of
February 7 1885.
No. 52.

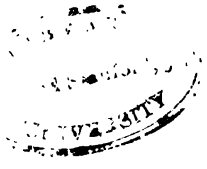


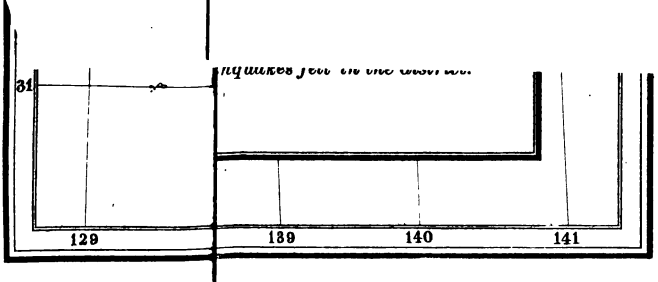

MAP IX.
Earthquake
of
August 29 1885.
No. 302.
MAP X.
Earthquake
of
September 5 1885.
No. 309.

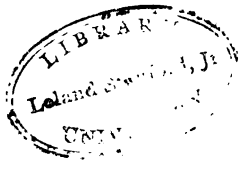



MAP VII.
Earthquake
of
June 1 1885.
No. 202.
MAP VIII.
Earthquake
of
August 13 1885.
No. 287.






31
129
139
140
141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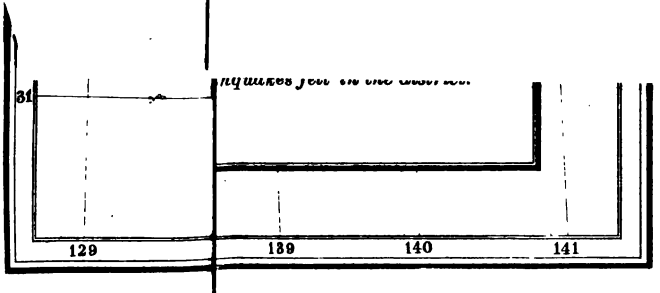
31
129
139
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141

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EARTHQUAKE CATALOGUES FOR 1881-1885.

In 1881 the Seismological Society of Japan published observation-books furnished with general directions for reporting on earthquakes. These were distributed to various observers throughout Japan with a request that copies of these observations should from time to time be forwarded to the Secretary of the Seismological Society. The following catalogue is the summary of all communications we have received since that time. Although they are not the most complete records of earthquakes which have been made in this country, we hope they will be of some assistance to those engaged in the compilation of earthquake catalogues. The following catalogues are arranged in chronological order, and the occurrence of shocks are recorded in local times. The latitudes and longitudes of the chief stations are given in the following list so that time corrections may be made. The society express their sincere obligation to the observers who have sent these reports, and are glad to mention their names and the number of observations they have forwarded as given in the following list:—

	Locality.	Latitude.	Longitude.	Names of Observers.	No. of Observations.
	Nemuro, Yezo	43° 20′ 16″ N.	145° 44′ 25″ E.	S Shibuya, Y. Sagisaka, Y. Hoshino, T. Tzujuki	115
	Sapporo, Yezo	43° 3′ 57″ N.	141° 22′ 37″ E.	S. Kimura, J. Summers, Wm. P. Brooks	16
	Hakodate, Yezo	41° 46′ 30″ N.	140° 40′ 24″ E.	Y. Sōma	5
	Kamaishi	39° 10′ 30″ N.	140° 52′ 50″ E.	T. Shishido, S. Sugiyama	29
	Innai Mines	39° 2′ 0″ N.	130° 3′ 0″ E.	T. Matsushita	9
	Yahiko, Yechigo	—	—	K. Futami	1
	Mito, Hidachi	36° 23′ 0″ N.	140° 44′ 25″ E.	M. Katagi	19
	Koguremura, Kozuke	—	—	Y. Watanabe	2
	Saitama	35° 52′ 0″ N.	139° 30′ 0″ E.	Normal School	7
	Gifu, Mino	35° 27′ 5″ N.	136° 40′ 52″ E.	R. Takasu	3
	Ogaki, Mino	35° 27′ 6″ N.	136° 31′ 0″ E.	K. Kishi	3
	Hiroshima	34° 20′ 0″ N.	132° 20′ 0″ E.	T. Hayami	13
	Wakayama, Kii	34° 14′ 0″ N.	135° 9′ 0″ E.	Meteorological Observatory	21
	Matzuye, Izumo	—	—	Meteorological Observatory	1
	Nagasaki	32° 44′ 17″ N.	129° 52′ 29″ E.	F. Ringer, Takibayashi	14
Philippine Islands.	Talacogon	8° 7′ 30″ N.	131° 24′ 0″ E.*	R. F. Heras	1
	Bislig	8° 12′ 15″ N.	132° 29′ 0″ E.*	R. F. Heras	2
	Louto	8° 31′ 25″ N.	131° 28′ 40″ E.*	R. F. Heras	1
	Banawan	8° 32′ 20″ N.*	131° 56′ 25″ E.	R. F. Heras	1
	Butuan	8° 50′ 40″ N.	131° 51′ 10″ E.*	R. F. Heras	1
	Manit	9° 2′ 0″ N.	131° 50′ 25″ E.*	R. F. Heras	1
	Lurigao	9° 42′ 20″ N.	131° 40′ 30″ E.*	R. F. Heras	1
	Yloilo	10° 42′ 30″ N.*	128° 46′ 30″ E.*	The Observatory	1
	Albay	13° 9′ 0″ N.	129° 54′ 0″ E.*	The Observatory	4
	Batagas	13° 58′ 0″ N.	127° 7′ 0″ E.*	The Observatory	1
	Taal	13° 50′ 0″ N.	127° 15′ 0″ E.*	The Observatory	1
	Sta Cruz de la Laguna	14° 18′ 0″ N.	127° 37′ 0″ E *	The Observatory	1
	Manila	14° 35′ 25″ N.	127° 9′ 33″ E.*	F. Faura	1
	San Yeidro	11° 20′ 30″ N.	127° 6′ 0″ E.*	The Observatory	2
	Cabanatuan	15° 31′ 50″ N.	127° 10′ 6″ E.*	The Observatory	1
	Lingayen	16° 2′ 30″ N.	126° 26′ 25″ E.*	The Observatory	1
	Tuguegarao	17° 36′ 42″ N.	8h. 31m. 29s. E.	Jose Le de Yrastorza	1
	Alcala	17° 48′ 0″ N.	127° 45′ 40″ E.*	The Observatory	1
	Bukeley, Alameda Co., California	—	—		1

* Longitude east of Fernando.

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
1	Sapporo	IV	18	15 50 0	1m 3s	NE and SW	Slight	Oscillatory	Wire of hanging lamp 4 feet long described an arc of 12 inches. Not personally observed: was walking on the street and nothing was noticed.
2	Nagasaki	V	22	19 22 0	About 30s	From W (?)	Slight	—	At the time of the shock, shaking noises were first audible on the western corner of the building; the observing station is 189 ft. about the sea level.
3	Nagasaki	V	22	19 31 0	—	From W (?)	Slight	—	
4	Nagasaki	V	22	19 42 0	—	From W (?)	Very slight	—	
5	Nagasaki	V	22	20 17 0	—	From W (?)	Slight	—	
6	Nagasaki	V	23	18 17 0	—	From W (?)	Very slight	—	
7	Nagasaki	V	23	22 8 0	10s	From W (?)	Slight	—	
8	Nagasaki	V	24	0 38 0	—	From W (?)	Very slight	—	
9	Nagasaki	V	26	4 50 0	—	—	Very slight	—	Asleep.
10	Nagasaki	V	27	8 16 27	4s	From SW (?)	Slight	—	
11	Nagasaki	V	31	8 48 0	—	From SW (?)	Slight	—	Six or seven shocks. Houses slightly shaken.
12	Saitama	VI	18	10 29 0	—	N-S	Slight	—	Trees feebly moved.
13	Wakayama ...	VI	30	14 17 20	—	ENE and WSW	Very slight	Only tremor	No sound. The observing station is built on sand bed 48 feet above the sea level
14	Kamaishi [Mine	VII	8	10 30 0	30s	NNW and SSE	—	Rolling	The office is situated on a feldspar rock about a mile from the Pacific coast and 60 feet above the mean water level. About the same time or a few minutes before the shock pheasants screamed. We have always a rolling sound just before the earthquake. The natives talk about the occurrence of earthquakes when long rain begins after fine weather.
15	Hiroshima ...	VII	10	15 45 0	—	From W	Very slight	—	
16	Wakayama ...	VII	11	11 27 30	—	NE and SW	Slight	—	Only a tremor, and no sound.
17	Nagasaki	VII	11	19 19 0	4s	From E	Slight	—	Barometer 30.047 reduced to 32° F.
18	Wakayama ...	VII	17	12 43 30	2m	E-W	Strong	Oscillatory	Very dull sound. Storms.
19	Kamaishi	VII	20	15 10 0	15s	—	—	—	Rolling after shocks.
20	Hiroshima ...	VII	21	21 0 0	—	From N	Very slight	—	

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
21	Ogaki.....	VII	22	4 30 0	Short	—	Feeble	—	The earthquake was at first sharp and people felt it as a vertical movement. The same earthquake was also felt in Gifu 5 *ri* from Ogaki. These cities are situated on an alluvial plain.
22	Kamaishi	VII	24	3 0 0	40s	—	—	Rolling	I was sleeping in a small house a *chō* from my office and was awakened by a loud noise; however, the shaking was not large. The house stands on an old river bed, now retained by rubble masonry.
23	Kamaishi	VII	27	11 35 0	10s	NNW by SSE	—	—	Rolling sound from the mountains was considerable before the earthquake.
24	Gifu	VIII	14	10 5 0	momentary	—	Very slight	Only tremor	The city stands on the west side of a hill.
25	Nagasaki	VIII	25	10 47 0	15s	From NW	Sharp	—	
26	Saitama	IX	4	10 45 0	—	E-W	—	—	15 or 16 shocks. Furniture rattled.
27	Kamaishi	IX	5	22 50 0	—	—	—	—	Only a shock and no sound.
28	Kamaishi	IX	7	22 0 0	—	—	—	—	A feeble shock, but awakened from sleeping.
29	Hiroshima ...	IX	10	18 30 0	—	W	Very slight	—	
30	Kamaishi	IX	20	15 8 0	50s	SSE to NNW	—	Rolling	The rolling sound proceeded from SSE toward NNW.
31	Hiroshima ...	IV	30	10 25 0	—	W	Very slight	—	
32	Nemuro.....	X	2	21 30 0	—	—	—	—	
	Kamaishi	X	2	22 5 0	4m	NNW by SSE	—	—	3 large shocks during the rolling.
33	Kamaishi	X	9	17 10 0	2m	NNW by SSE	—	Rolling	At the same time pheasants cried out.
34	Kamaishi	X	10	21 3 0	3m	NNW by SSE	—	Rolling	
	Kamaishi	X	19	21 23 0	1m 30s	NNW by SSE	—	Rolling	3 considerable shocks, the middle one being the largest.
35	Nemuro.....	X	19	21 28 0	—	—	—	—	One jump.
	Hakodate	X	19	21 29 15	20s	—	Slight	—	One jump.
36	Sapporo.....	X	22	6 20 0	Very short	—	Slight	—	
37	Hakodate	X	24	14 57 32	1 or 2s	—	Very slight	—	Two jumps.
38	Sapporo.....	X	25	21 30 0	3m	—	Rough	Undulatory	
	Kamaishi	X	25	21 30 0	3m	SSE to NNW	Strong	Rolling	A hanging lamp 4 *shaku* long vibrated half a sun; pheasants cried loudly one or two minutes before the earthquake and also after it.
	Hakodate	X	25	21 41 0	1m 45s	From SE	Slight	Oscillatory	The observer's house is situated on the slope of hills, built on stone foundation, wooden frame.
39	Kamaishi	X	29	3 20 0	3s	SSE-NNW	—	Rolling	
40	Kamaishi	XI	2	3 14 0	1s	—	—	Momentary shock	

41	Ogaki.....	XI	4	4 40 0	—	From N	Slight	—	Accompanied by a slight sound.
42	Hiroshima ...	XI	6	10 40 0	—	—	Slight	—	
43	Gifu	XI	11	3 12 1	Moderately long	—	Slight	—	A few oscillations.
44	Kamaishi	XI	11	9 10 0	$1\frac{1}{2}$s	—	—	Rolling	
45	Kamaishi	XI	12	3 30 0	4s	—	—	—	Three prominent shocks.
46	Saitama	XI	15	22 10 0	—	E-W	—	—	More than ten shocks.
47	Yahiko (Yechigo	XI	15	22 30 0	1m	From NW	Pretty large	—	The village stands on the foot of Asakusayama.
48	Saitama	XI	18	19 29 0	—	From N	—	—	Houses made a little sound, and trees little vibrated. Some 67 oscillations were counted.
49	Hiroshima ...	XI	27	21 10 5	—	From W	Slight	Oscillatory	
?50	Gifu	XII	5	14 28 0	20s	—	Pretty strong	—	Loud sound was audible at the time of the earthquake.
	Ogaki	XII	5	13 30 2	12s	From SW	Pretty strong	Rolling	
51	Kamaishi	XII	9	22 15 0	2m	—	Strong	Rolling	
52	Kamaishi	XII	25	15 0 0	30s	—	—	Rolling	
53	Kamaishi	XII	25	22 0 0	1m 30s	—	—	Rolling	
54	Kamaishi	XII	26	14 0 0	1m 30s	—	—	Rolling	

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1	Innai (Mine).	I	6	5 30 0	—	—	Very slight	—	It was so feeble that those who were asleep did not feel it. The mine passes through the tertiary tuffa.
2	Kamaishi	I	7	22 30 0	1m	—	—	Rolling	
3	Kamaishi	I	9	17 20 0	1m 30s	—	—	Rolling	
4	Nagasaki	I	10	7 2 0	3s	From S	—	Sharp	
5	Nagasaki	I	10	7 10 5	Very short	N and S	Rather	—	Very short and sharp concussions like a big gun.
6	Innai	I	11	6 40 0	—	—	Very slight	—	
7	Innai	I	11	7 0 0	—	—	Feeble	—	Glass windows rattled. Nothing occurred to the mine.
8	Nemuro.....	I	15	16 40 50	25s	SSE	Feeble	Undulatory motions	
9	Nemuro.....	I	16	4 33 0	—	—	Very slight	Vertical motion	
10	Nemuro.....	I	16	15 27 25	27s	NNE	Violent	Undulatory	
11	Nemuro.....	I	22	9 41 35	40s	NNE	Violent	Undulatory	
12	Nemuro.....	I	22	11 36 20	—	NNE	Very slight	Vertical motion	

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
13	Kamaishi	I	25	3 10 0	2m 30s	—	—	Rolling	
14	Kamaishi	I	26	7 40 0	1m 30s	—	—	Rolling after a shock	
15	Hiroshima	I	26	9 45 0	—	From W	Slight	Oscillatory	
16	Kamaishi	I	30	2 30 0	2m	—	—	Rolling	
17	Kamaishi	I	31	17 30 0	30s	—	—	Rolling	This was the largest earthquake that I have experienced here.
	Innai	I	31	17 35 10	15s	—	—	—	People who were asleep did not feel it.
18	Nemuro	II	3	6 20 0	1m 45s	NNE	Violent	Horizontal oscillations	
19	Nemuro	II	4	10 15 0	—	NNE	Very slight	Vertical motion	
20	Nemuro	II	9	10 3 0	—	NNE	Very slight	Vertical motion	
21	Nemuro	II	9	17 37 0	28s	NNE	Strong	Undulatory	
22	Hiroshima	II	11	9 0 0	—	—	Very slight	—	[affected.
23	Innai	II	11	23 55 0	—	—	Slight	—	Last a single vertical shock; hanging lamp was not
24	Nemuro	II	13	0 18 15	1m 10s	From SSE	Violent	Undulatory	
25	Innai	II	14	11 15 0	—	—	Slight	—	After 5 minutes another shock was felt. All people seemed to have noticed these shocks.
26	Nemuro	II	16	5 1 18	1m 27s	SSE	Feeble	Undulatory	
27	Nemuro	II	20	17 10 0	—	—	Feeble	Vertical motion	
28	Nemuro	II	27	11 5 15	1m 40s	SE	Feeble	Undulatory	
29	Nemuro	II	27	20 25 0	—	—	Very feeble	—	
30	Saitama	III	1	2 0 0	—	NNW and SSE	—	—	Furniture rattled. Some 20 distinct shocks.
31	Saitama	III	1	4 0 0	—	NNW and SSE	—	—	
32	Nemuro	III	3	10 29 45	7s	SSE	Feeble	Vertical motion	
33	Nemuro	III	7	12 54 0	—	—	Feeble	—	
34	Kamaishi	III	8	16 0 0	4m	—	—	Oscillatory	No sound.
	Hakodate	III	8	16 16 10	2m 30s	From SW to NE	Strong	—	
	Innai	III	8	16 20 0	[About 10s	N-S?	Feeble	—	No accident in the mine, although it was said that the people thought the shocks have been stronger there than it was on the outside. Furniture rattled and people felt the motion on their seats. It always seems to me that the seismic waves propagate from the north toward the south.

	Nemuro.....	III	8	16 40 20	3m 10s	From SE	Feeble	?	
35	Kamaishi.....	III	8	22 0 0	5m	—	Strong	Horizontal oscillation	The shakings which nearly subsided in about two and half minutes were followed by another shock of almost equal duration. The earthquake has been the greatest and largest that I have ever experienced in this quarter. Japanese houses have been violently shaken; the joints of houses creaked; every body ran out of their dwellings.
	Saitama	III	8	23 25 0	Pretty long	NNW and SSE	Moderate	—	
36	Nemuro.....	III	8	23 44 30	—	—	—	—	
	Innai	III	8	23 45 0	—	N-S?	Very feeble	—	
37	Nemuro.....	III	9	0 11 50	30s	SSE	Feeble	Rolling	
38	Kamaishi.....	III	9	21 40 0	1m	—	—	—	
39	Nemuro.....	III	10	7 30 0	—	—	Feeble	Vertical motion	
40	Kamaishi.....	III	11	15 45 0	—	—	—	—	
41	Matsuye (Izumo).....	III	21	4 20 0	—	—	—	—	The shock awakened me from sound sleep.
42	Kamaishi.....	III	21	6 11 0	—	—	—	Rolling	
43	Hiroshima ...	III	25	20 45 0	—	From W	Very slight	Sudden jerk	
44	Hiroshima ...	III	25	22 45 0	—	From W	Very slight	Rolling	
45	Nemuro.....	IV	1	5 46 0	—	ESE	—	—	
46	Nemuro.....	IV	8	8 29 0	1m 30s	ESE	Strong	Vertical motion	
47	Nemuro.....	IV	10	16 46 0	2m 20s	ESE	Strong	Rotatory?	
48	Nemuro.....	IV	11	12 45 0	—	ESE	Feeble	?	
49	Nemuro.....	IV	18	18 27 30	30s	ESE	Feeble	?	
50	Nemuro.....	V	9	1 42 0	—	—	—	—	
51	Nemuro.....	V	9	18 59 30	—	—	—	—	
52	Nemuro.....	V	29	15 28 30	25s	NE	Feeble	Undulatory	
53	Nemuro.....	V	29	18 59 30	—	—	—	Undulatory	
54	Nemuro.....	VI	1	19 5 0	15s	NNE	Slight	—	
55	Nemuro.....	VI	2	3 58 50	1m	ESE	Slight	Undulatory	
56	Nemuro.....	VI	2	7 31 0	—	—	—	—	
57	Nemuro.....	VII	1	6 36 0	1m	From ESE	Feeble	Undulatory	
58	Nemuro.....	VII	24	8 30 0	50s	S	Violent	Undulatory	
59	Nemuro.....	VIII	8	15 11 0	30s	N-E	Slight	Rotatory?	
60	Nemuro.....	VIII	15	10 28 50	40s	SSE	Slight	Rotatory?	
61	Kogure (Kozuke)	VIII	18	17 40 0	2m	—	—	—	

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
62	Nemuro.....	VIII	18	23 40 0	30s	—	—	Rotatory	
63	Nemuro.....	IX	5	5 59 0	4m	S-E	Violent	Vertical motion	
64	Sapporo.....	X	1	19 10 15	20 or 30s	W-E (?)	Moderate	Oscillation	The intensity increased like a wave swell. Preceded and followed by tremors.
65	Nemuro.....	X	8	17 50 0	—	ENE	Feeble	—	
66	Nemuro.....	X	14	15 35 0	—	—	Feeble	—	
67	Kogure	X	20	3 35 0	15s	—	—	—	
68	Hiroshima ...	X	24	20 10 0	—	S (?)	Very slight	Sudden jerk	
69	Nemuro.....	XI	18	15 35 0	1m	N-E	Violent	—	[earthquake.
70	Hiroshima ...	XI	26	14 25 0	—	NW (?)	Slight	Sudden jerk	The rumbling of the earth was heard before the
71	Hiroshima ...	XI	26	16 15 0	—	—	Very slight	—	
72	Nemuro.....	XII	6	5 45 0	1m 30s	From NW	Violent	Rotatory	
73	Mito	XII	23	11 45 0	2s	WE	Slight	Horizontal oscillations	
74	Nemuro.....	XII	27	0 10 0	—	N-E	Feeble	Undulatory	
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1	Sapporo.....	I	3	15 55 0	7s	W-E	Very slight	Gentle oscillations	By seismograph it was only a slight shock.
2	Mito	I	4	5 23 0	2m	E-W	Slight	Horizontal oscillation	
3	Mito	I	7	10 0 0	1m	N-W	Feeble	Horizontal oscillation	
4	Mito	I	12	1 4 0	5m	N-E	Pretty strong	Horizontal oscillation	
5	Mito	I	12	14 20 0	5m	N-W	Pretty strong	Horizontal oscillation	
6	Mito	I	14	2 8 0	3m	E-W	Weak	Horizontal oscillation	
7	Mito	I	18	4 40 0	13s	S-E	Strong	Horizontal oscillation	
8	Mito	I	18	19 56 0	2m	S	Weak	Horizontal oscillation	
9	Mito	I	19	8 14 0	4m	E	Strong	Horizontal oscillation	

10	Innai	I	22	0 10 0	About 10s	N-S	Very slight	Horizontal oscillations	Both water in a basin and a hanging lamp oscillated NS. The offices of the mine are situated on decomposed tuffa at a junction of two valleys. The windows rattled.
	Mito	I	22	0 24 0	3m	N-S	Violent	Horizontal oscillations	
11	Nemuro	I	23	11 41 0	1m	S-W	Strong	Undulatory	
12	Sapporo	I	23	16 48 0	5s	From SSW to NNE	Very slight	Gentle oscillations	A seismograph registered small motion.
13	Mito	I	25	5 25 0	2m	S-E	Feeble	Horizontal oscillations	
14	Mito	I	26	8 25 0	1m	S	Very feeble	Horizontal oscillations	
15	Mito	I	27	18 33 0	3m	E	Feeble	Horizontal oscillations	
16	Mito	I	31	12 10 0	5m	N-W	Rather weak	Horizontal oscillations	Stormy weather.
17	Mito	I	31	12 45 0	2m	W	Weak	Horizontal oscillations	Stormy weather.
18	Mito	I	31	13 3 0	8s	From S	Strong	—	Stormy weather.
19	Nemuro	II	6	12 16 20	52s	From SW	Feeble	Undulatory	
20	Mito	II	9	12 0 0	3s	E	Feeble	Horizontal oscillations	
21	Mito	II	14	21 35 0	2s	S	Feeble	Horizontal oscillations	
22	Mito	II	21	1 50 0	2s	S-E	Feeble	Horizontal oscillations	
23	Sapporo	II	26	11 20 0	About 6s	From SSE to NNW	Very slight	Gentle horizontal oscillations	No damage.
24	Sapporo	II	28	14 2 0	About 9s	From W to E	Very slight	Gentle horizontal oscillations	
	Nemuro	II	28	14 25 0	1m	—	Strong	Vertical motion	
25	Nemuro	III	13	22 25 0	1m 30s	S-W	Very strong	Upheaving	
26	Nemuro	III	25	22 11 30	55s	From SE	Strong	Undulatory	
27	Nemuro	III	25	22 32 35	15s	—	Strong	Upheaving	
28	Nemuro	III	26	12 52 15	25s	SE	Violent	Undulatory	
29	Nemuro	III	26	6 10 0	15s	SE	Slight	Undulatory	
30	Nemuro	III	26	20 19 15	5s	SE	Slight	Undulatory	
31	Nemuro	III	29	19 15 50	5s	SSE	Slight	Upheaving	

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32	Nemuro.....	IV	14	10 30 20	—	SSW	Slight	Undulatory	
33	Hakodate.....	IV	20	2 58 0	1m 48	—	Rough	—	Shocks of different intensities came in succession: at first slight, then strong, then slight, strong again, and so on.
	Sapporo	IV	20	3 5 0	1m	From NNE	Rough	—	No damage.
34	Sapporo	IV	20	3 58 0	10s	—	Slight	Gentle oscillation	
35	Nemuro.....	IV	25	20 18 0	—	W	Slight	—	
36	Nemuro.....	VII	4	2 57 0	15m (?)	From NE	Slight	Undulatory	
37	Nemuro.....	VII	8	3 20 0	25m (?)	NNE	Strong	Undulatory	
38	Nemuro.....	VII	9	15 22 0	—	NNW	Feeble	Undulatory	
39	Nemuro.....	VII	14	21 7 0	—	—	—	—	
40	Nemuro.....	VII	26	1 22 0	1m 50s	WNW	Violent	Undulatory	
41	Nemuro.....	VII	29	11 57 0	1m	SSE	Strong	Undulatory	
42	Nemuro.....	VIII	2	9 4 40	1m 40s	N	Strong	Undulatory	
43	Nemuro.....	IX	5	13 47 0	1m 30s	N	Strong	Rotatory	
44	Nemuro.....	X	5	5 19 0	—	—	—	—	
45	Nemuro.....	X	8	18 16 0	—	—	Slight	—	
46	Nemuro.....	X	10	12 10 40	—	—	—	—	
47	Sapporo	X	14	Night	7s	E-W	Slight	Gentle oscillations	No damage.
48	Nemuro.....	X	20	15 15 0	40s	—	—	—	
49	Nemuro.....	X	22	22 12 0	—	—	Strong	—	
50	Sapporo	X	28	14 0 0	5s	W-E	Slight	Gentle oscillations	No damage.
51	Sapporo.....	XI	10	7 5 15	45s	S-W	—	sudden jerks	No damage.
	Nemuro.....	XI	10	7 30 0	2m 30s	—	—	—	
52	Nemuro.....	XI	10	12 40 0	1m 30s	—	Strong	—	
53	Sapporo.....	XI	10	15 0 0	7s	NW-S	Slight	Gentle oscillations	No damage.
54	Sapporo.....	XI	11	9 0 0	5s	S	Slight	Gentle oscillations	No damage.
55	Nemuro.....	XI	12	2 10 0	—	—	Strong	—	
56	Nemuro.....	XI	13	19 2 0	—	—	—	—	
57	Nemuro.....	XI	30	19 25 0	—	—	Strong	—	
58	Nemuro.....	XII	9	16 55 0	—	—	Strong	—	
59	Nemuro.....	XII.	26	18 0 0	—	—	—	—	
60	Nemuro.....	XII	26	18 30 0	—	—	—	—	

1	Nemuro.....	I	1	20 30 0	—	—	—	—	
2	Nemuro.....	I	23	6 26 0	—	—	Strong	—	
3	Nemuro.....	III	14	16 4 0	—	—	—	—	
4	Nemuro.....	III	20	20 2 0	3m 10s	—	—	—	
5	Nemuro.....	IV	17	12 26 10	—	—	—	—	
6	Nemuro.....	IV	17	18 0 0	—	—	—	—	
7	Nemuro.....	V	8	19 45 0	—	—	Strong	—	
8	Nemuro.....	V	14	16 54 0	—	—	Strong	—	
9	Nemuro.....	V	16	21 11 0	—	—	Strong	—	
10	Nemuro.....	V	25	22 40 0	—	—	Strong	—	
11	Nemuro.....	V	27	9 32 30	—	—	Strong	—	
12	Nemuro.....	VI	10	18 50 0	—	—	Feeble	—	
13	Nemuro.....	VI	16	11 50 0	—	—	—	—	
14	Nemuro.....	VI	19	13 33 0	—	—	—	—	
15	Nemuro.....	VI	27	14 51 0	3m	—	Strong	—	
16	Nemuro.....	VII	12	7 24 0	1m 50s	From SW	Strong	—	
17	Nemuro.....	VIII	4	9 10 0	1m 30s	From E	Strong	—	
18	Nemuro.....	VIII	5	14 52 0	1m 30s	—	—	—	
19	Nemuro.....	VIII	9	22 31 0	—	—	Strong	—	
20	Nemuro.....	VIII	22	12 25 0	40s	—	—	—	
21	Nemuro	VIII	25	10 34 0	—	—	—	—	
22	Nemuro.....	VIII	25	11 56 0	40s	—	—	—	
23	Nemuro.....	X	7	1 46 0	2m	—	Very violent	—	
24	Nemuro.....	XI	10	4 0 0	50s	—	—	—	
25	Nemuro.....	XII	9	22 52 40	1m 30s	From SW	Very violent	—	
26	Nemuro.....	XII	12	6 53 0	40s	—	Strong	—	
27	Wakayama ...	XII	22	11 42 7	5s	NW and SE	Slight	—	Far away in the north-west a rolling sound was audible, and in another moment we felt as if the house was suddenly moved to S.E.
28	Wakayama ...	XII	22	23 36 18	18s	E and W	Slight	—	
29	Nemuro.....	XII	24	20 48 0	38s	—	Strong	—	
30	Wakayama ...	XII	30	17 48 40	40s	E and W	Weak	—	A sound like distant thunder was audible in a western direction and was followed by sudden shocks. As the disturbance subsided the rolling noise appeared as if it proceeded to the eastern horizon.

1885.

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
1	Wakayama ...	II	12	16 26 45	5s	E and W	Weak	—	
2	Wakayama ...	II	28	20 15 5	15s	E and W	Moderate	Horizontal oscillations	
3	Nemuro.....	III	8	5 40 0	2m 30s	NNW	Strong	Undulatory	
	Sapporo.....	III	8	morning	—	S-W	Moderate	Gentle oscillations	No damage.
4	Nemuro.....	III	23	5 54 0	1m	—	Moderate	—	
5	Nemuro.....	III	24	23 50 0	40s	—	Moderate	—	
6	Wakayama ...	III	31	7 55 0	15s	W-E	Slight	Horizontal oscillations	No sound.
7	Nemuro.....	IV	21	15 45 0	—	—	Feeble	—	
8	Wakayama ...	V	1	2 43 5	4s	E and W	—	Horizontal oscillations	No sound.
9	Wakayama ...	V	3	3 57 5	25s	N and S	—	—	There were three periods in this earthquake; in the first 10 seconds the motion was feeble, it then augumented for 5 seconds, after which the shaking was again slight till the end.
10	Nemuro.....	V	9	11 25 0	25s	—	Strong	—	
11	Wakayama ...	V	25	3 4 45	7s	E and W	Slight	—	
12	Nemuro.....	VI	8	13 20 0	—	—	—	—	
13	Sapporo.....	VI	11	9 24 0	59s	SE-NW	Moderate	Gentle oscillations	No damage.
14	Wakayama ...	VI	14	21 33 21	25s	E-W	Weak	Horizontal oscillations	[direction. Underground noise was audible in an eastern
15	Wakayama ...	VII	14	20 17 0	10s	N-S	Feeble	—	Noises like distant thunder were heard in the south.
16	Wakayama ...	VII	28	8 50 45	5s	SW and EN	Feeble	Horizontal oscillations	
17	Wakayama ...	VIII	8	8 4 0	6s	S-W	—	Horizontal oscillations	
18	Wakayama ...	VIII	29	0 23 20	28s	E-W	Weak	Horizontal oscillations	No sound.
19	Wakayama ...	IX	18	12 33 23	6s	SW-NE	Feeble	Horizontal oscillations	No sound.
20	Wakayama ...	X	16	5 58 0	—	—	Weak	—	

21	Sapporo.....	X	30	20 33 58	18s	S-N	Slight	Gentle oscillations	No damage.
22	Wakayama ...	XI	12	21 7 15	11s	NE and SW	Feeble	Horizontal oscillations	Feeble underground noise was audible like distant firing of guns.
23	Wakayama ...	XII	22	11 15 50	6s	E-W	Weak	Horizontal oscillations	

1881.

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
	Juguegarao ...	I	21	5 31 0	5s	—	Small	Trepidation	
	Manila	II	2	9 15 0	25s	NE to SW	Small	Oscillation	
	Taal	II	3	5 30 0	Short	—	Sudden	—	
	Batangas	II	3	5 36 0	15s	N-S	Strong	Oscillation	
	Surigao	II	7	0 0 0	—	—	—	—	
	Albay	II	12	18 12 0	2s	—	Slight	Oscillation	Repeated several times.
	Albay	II	12	19 9 0	—	—	Slight	Oscillation	
	Talacogon ...	II	18	21 30 0	—	—	Strong	—	
	Lingayen	II	21	4 0 0	—	—	Strong	—	
	Albay	III	4	—	—	N-S	—	Oscillation	
	Bunauan	III	7	23 0 0	—	—	—	—	
	Yloilo	III	12	13 40 0	Short	—	—	—	
	Bislig	III	14	13 30 0	—	—	—	—	
	Bislig	III	14	22 0 0	—	—	—	—	
	Alcala	III	16	4 45 0	9s	E-W	Quick	Oscillations	
	Butuan	III	23	15 30 0	—	—	Very strong	—	
	Loreto	III	23	15 30 0	—	—	Very strong	—	
	Mainit	III	23	15 30 0	—	—	Very strong	—	
	Berkeley, Almeda Co., California ..	V	14	13 9 0	2s or 3s	SE-NW	Slight tremors	—	Preceded and accompanied by a rumbling sound.
	San Yeidro ...	V	16	11 37 0	Momentary	—	Moderate	—	
	Cabanatuan...	V	16	11 37 0	Momentary	NE-SW	Moderate	—	
	San Yeidro ...	V	16	11 39 0	4s	—	Moderate	—	

No.	Locality.	Month.	Day.	Time.	Duration.	Direction.	Intensity.	Nature.	Remarks.
	Sta Cruz de la Laguna	V	17	2 15 0	Short	NE-SW	—	Oscillation	
	Albay.....	V	20	7 35 0	—	—	Slight	Trepidation	
{	Paltod	V	25	10 9 0	20s	—	Slight	Oscillation	
{	Talaban	V	25	10 20 0	10s	N-S	Slight	Oscillation	
					1883.				
	Berkeley, Almeda Co., California ..	I	23	23 40 0	15-25	NE and SW (?)	Slight	—	First concussion; then tremor accompanied by rumbling sound.

CATALOGUE OF EARTHQUAKES

(May, 1885 to January, 1887).

Recorded by the Gray-Milne Seismograph at the Imperial Meteorological Observatory (Chirikioku), Tokio.

(For first portions of this Catalogue see Trans. Seis. Soc. Vol. II., pages 3-39, Vol. VI., page 32-35, Vol. VIII., page 100-108.)

1885.

No.	Month.	Day.	Time.	Period in Seconds.	Amplitude in M.M.	Direction.	Duration.
			h. m. s.				m. s.
607	V	1	2 47 27 a.m.	—	—	—	—
608	V	7	8 58 08 a.m.	—	—	—	2 49
609	V	19	abt. 2h 50m a.m.	—	—	—	—
610	VI	7	11 34 18 p.m.	—	—	—	—
611	VI	11	9 19 40 a.m.	2.2	1.6	W 11° N	6 38
612	VI	15	1 41 41 a.m.	2.3	5.9	E 9° S	6 00
613	VI	15	8 40 00 a.m.	—	—	—	—
614	VI	18	1 36 45 p.m.	1.8	0.8	W 11° N	2 30
615	VI	28	2 24 18 a.m.	—	—	—	—
616	VIII	26	5 02 30 a.m.	—	—	—	—
617	VIII	28	9 37 28 a.m.	—	—	E or W	32
618	VIII	31	5 23 55 a.m.	—	—	N or S	10
619	IX	2	8 31 42 a.m.	0.4	0.4	N 19° E	25
620	IX	10	8 19 06 p.m.	—	—	—	—
621	IX	11	1 24 30 a.m.	—	—	—	10
622	IX	20	1 13 50 a.m.	0.4	0.4	WSW or ENE	24
623	IX	22	2 29 43 a.m.	1.6	0.8	E 27° S	1 20
624	IX	26	0 02 45 p.m.	3.0	13.7	N 7° E	9 00
625	IX	28	5 27 43 a.m.	2.2	11.1	E 17° S	4 00
626	IX	29	8 39 09 a.m.	—	—	N or S	—
627	X	1	1 08 57 p.m.	0.5	0.8	S 42° E	1 14
628	X	7	7 34 45 a.m.	—	—	E or W	41
629	X	9	7 53 05 p.m.	—	—	E or W	1 12
630	X	11	abt. 5h 30m a.m.	—	—	N or S	1 30
631	X	15	9 02 29 a.m.	—	—	N or S	1 07
632	X	15	8 43 18 p.m.	1.1	0.3	E 29° S	1 10
633	X	21	1 19 35 a.m.	0.9	0.2	E 29° S	1 20
634	X	24	5 12 58 a.m.	0.9	0.2	E 28° N	1 39
635	X	26	10 41 11 p.m.	2.9	1.9	N 45° W	4 48
636	X	30	8 31 16 p.m.	1.5	0.2	E 17° 30′ S	2 05
637	IX	11	8 51 24 p.m.	—	—	E or W	—
638	IX	16	1 50 36 p.m.	0.7	0.2	E 27° S	30
639	IX	20	7 41 35 p.m.	—	—	SE or NW	—
640	XII	3	6 01 42 a.m.	0.5	0.2	SW or NE	50
641	XII	6	8 13 00 p.m.	—	—	E or W	—
642	XII	7	1 02 23 p.m.	3.0	4.0	E 12° S	5 00

No.	Month	Day.	Time.	Period in Seconds.	Amplitude in M.M.	Direction.	Duration.
			h. m. s.				m. s.
643	XII	7	7 56 57 p.m.	—	—	E or W	—
644	XII	18	3 00 38 a.m.	—	—	—	—
645	XII	19	6 26 40 p.m.	1.0	1.8	W 29° N	2 43
646	XII	28	10 06 30 p.m.	1.8	3.3	E 11° N	3 40
			1886.				
647	I	5	4 23 42 p.m.	0.8	0.4	N 26° E	23
648	I	22	10 58 00 a.m.	Very	slight	S-N	15
649	I	31	7 22 46 a.m.	Very	slight	S-N	—
650	II	19	2 54 11 a.m.	Very	slight	E-W	—
651	II	24	7 34 00 a.m.	0.6	0.5	N 40° E	1 24
652	II	24	3 36 25 p.m.	—	0.2	E-W	1 20
653	III	2	5 03 49 a.m.	1.4	0.4	N 25° 30′ W	1 55
654	III	13	6 25 00 p.m.	1.4	0.3	W 33° N	33
655	III	26	6 06 00 a.m.	Very	slight	S-N	10
656	IV	13	5 45 00 a.m.	1.4	0.7	S 33° E	3 10
657	IV	23	4 22 22 a.m.	1.8	0.3	S-N	33
658	V	3	Noon	—	0.2	E-W	1 30
659	V	8	10 14 00 p.m.	0.4	2.8	W 39° 30′ N	1 40
			Vertical	0.3	0.5	—	—
660	V	9	abt. 3h 10m p.m.	2.2	0.3	W 37° 50′ N	1 40
661	V	11	2 31 58 p.m.	Very	slight	SE-NW	30
662	V	12	11 43 49 a.m.	—	0.04	NE-SW	30
663	V	16	9 03 00 a.m.	0.7	1.7	E 27° S	3 00
			Vertical	0.4	0.9	—	—
664	V	18	8 12 51 p.m.	1.7	0.4	E 16 S	2 25
665	V	30	8 38 18 p.m.	Very	slight	—	about 10
666	VI	3	3 06 37 p.m.	—	—	SE or NW	—
667	VI	11	1 45 44 p.m.	0.6	0.2	SSE or NNW	45
668	VI	14	6 25 19 p.m.	—	—	SE or NW	25
669	VI	14	6 56 09 p.m.	0.3	0.4	S 45° E	1 10
670	VII	2	0 33 06 p.m.	1.2	0.7	S 26° E	3 30
			Vertical motion	0.7	0.2	—	—
671	VII	23	0 57 00 a.m.	1.9	0.5	S or N	1 04
672	VIII	3	2 11 45 a.m.	—	—	E or W	20
673	VIII	9	10 24 00 a.m.	2.4	0.7	E or W	3 00
674	VIII	10	8 53 43 p.m.	0.8	0.2	E or W	17
675	VIII	11	9 52 33 p.m.	1.2	0.2	E or W	2 00
676	VIII	12	2 54 45 p.m.	—	—	—	—
677	VIII	13	11 40 26 p.m.	—	—	—	—
678	VIII	19	0 09 23 a.m.	0.4	0.2	E or W	14
679	VIII	29	8 34 54 p.m.	—	—	NNE or SSW	20
680	XI	6	0 38 53 p.m.	1.0	0.2	ESE or NNW	10
681	XI	12	8 43 22 p.m.	1.0	0.3	E 20° 20′ N	1 00
682	XI	15	3 9 23 a.m.	Very	slight	E-W	26
683	XI	16	1 2 57 p.m.	Very	slight	SE-NW	40
684	XI	20	abt. 1 40 0 p.m.	—	—	—	—
685	XI	21	8 17 9 p.m.	Very	slight	E-W	1 5
686	XI	30	10 36 8 a.m.	Very	slight	S-N	—
687	X	4	1 35 25 p.m.	0.5	0.3	E-W	30
			Vertical	—	0.3	—	—
688	X	22	3 49 14 a.m.	Very	slight	S-N	50
689	X	25	10 11 18 p.m.	0.8	0.3	ESE-WNW	39
			Vertical motion very slight				
690	X	30	4 35 17 p.m.	Very	slight	E-W	10
691	XI	1	5 13 5 a.m.	0.4	0.3	E 34° S	10
692	XI	2	8 21 46 a.m.	Very	slight	SE-NW	30
693	XII	4	2 00 39 p.m.	0.5	0.4	SE-NW	2 10
			Vertical motion	0.5	0.4	—	—
694	XII	6	0 45 46 p.m.	Very	slight	—	—
695	XII	8	11 58 16 p.m.	0.5	0.2	E 27° N	35

No.	Month.	Day.	Time.	Period in Seconds.	Amplitude in M.M.	Direction.	Duration.
			h. m. s.				m. s.
696	XII	11	10 16 25 p.m.	1.5	0.2	E-W	28
697	XII	12	10 11 55 p.m.	2.2	3.5	E 37° S	4 30
			Vertical motion	Very	slight	—	—
698	XII	21	3 7 2 a.m.	Very	slight	S-N	—
699	XII	26	5 48 5 p.m.	0.2	1.0	N 35° W	30
			Vertical motion	Very	slight	—	—
700	XII	29	11 5 43 a.m.	0.6	0.4	ESE-WNW	45
			Vertical motion	Very	slight	—	—
			1887.				
701	I	15	6 51 59 p.m.	2.3	19.2	E 34° N	10 0
			Vertical motion	0.8	5.5	—	—
702	I	15	7 36 40 p.m.	0.4	0.4	E 36° N	1 30
			Vertical motion	Very	slight	—	—
703	I	16	10 16 19 p.m.	0.4	0.7	E-W	1 17
704	I	16	10 31 0 p.m.	—	—	—	—
705	I	16	10 54 18 p.m.	—	—	—	—
706	I	17	8 59 34 a.m.	—	—	—	—
707	I	21	11 46 43 p.m.	—	0.2	E-W	25
708	I	23	9 16 55 p.m.	1.0	0.2	SSE-NNW	35
709	I	24	10 40 50 p.m.	Very	slight	—	—

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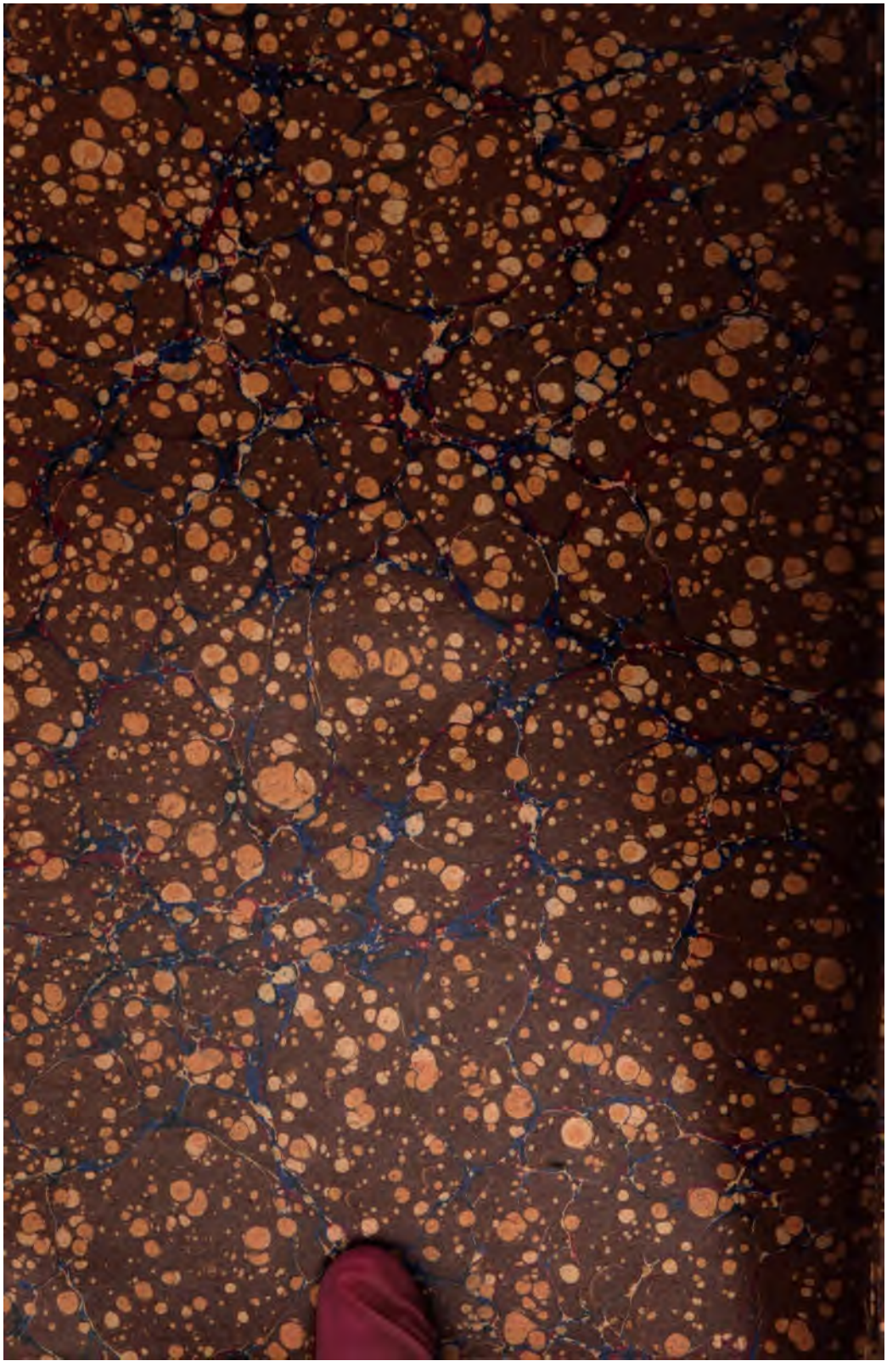

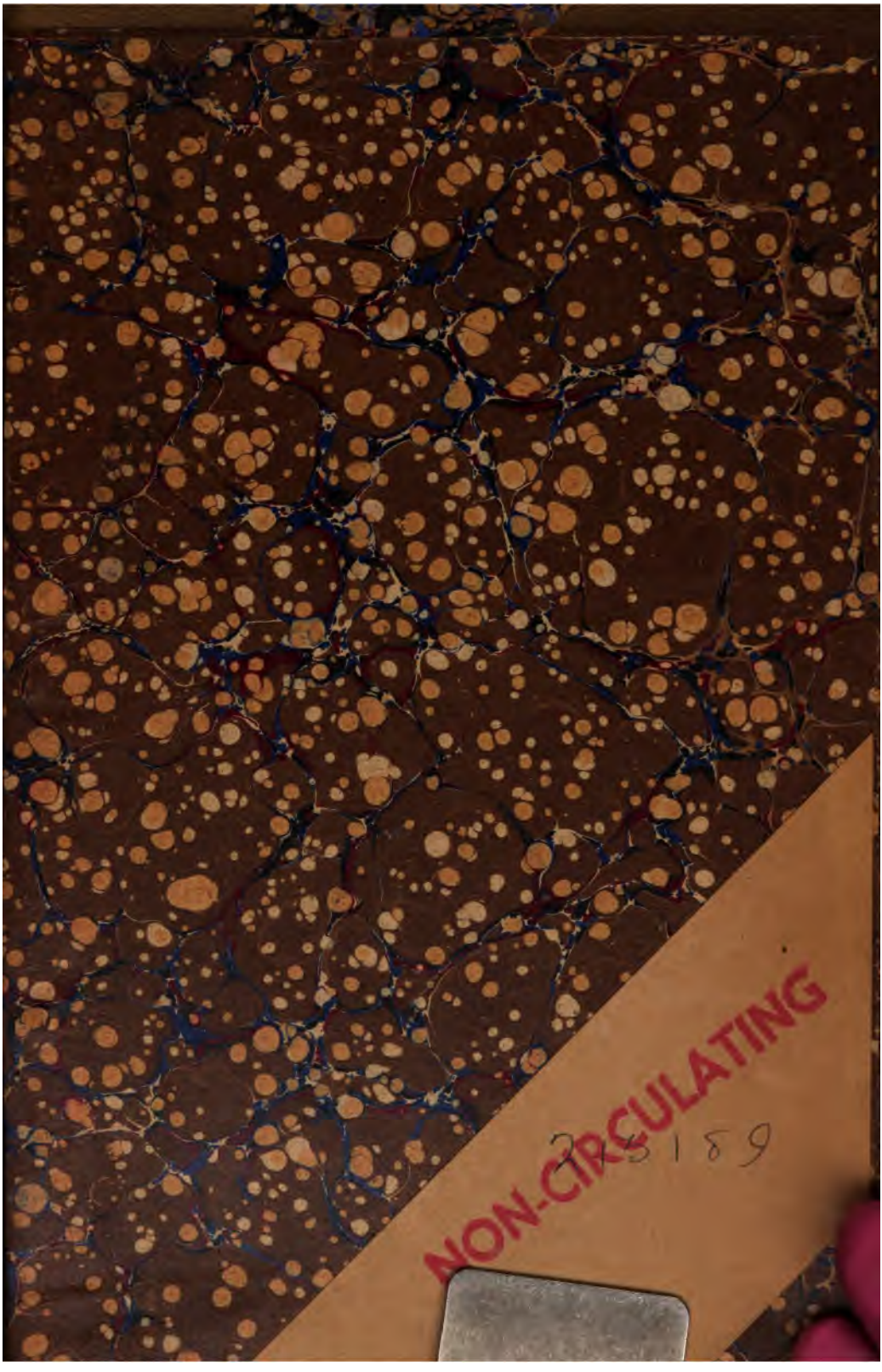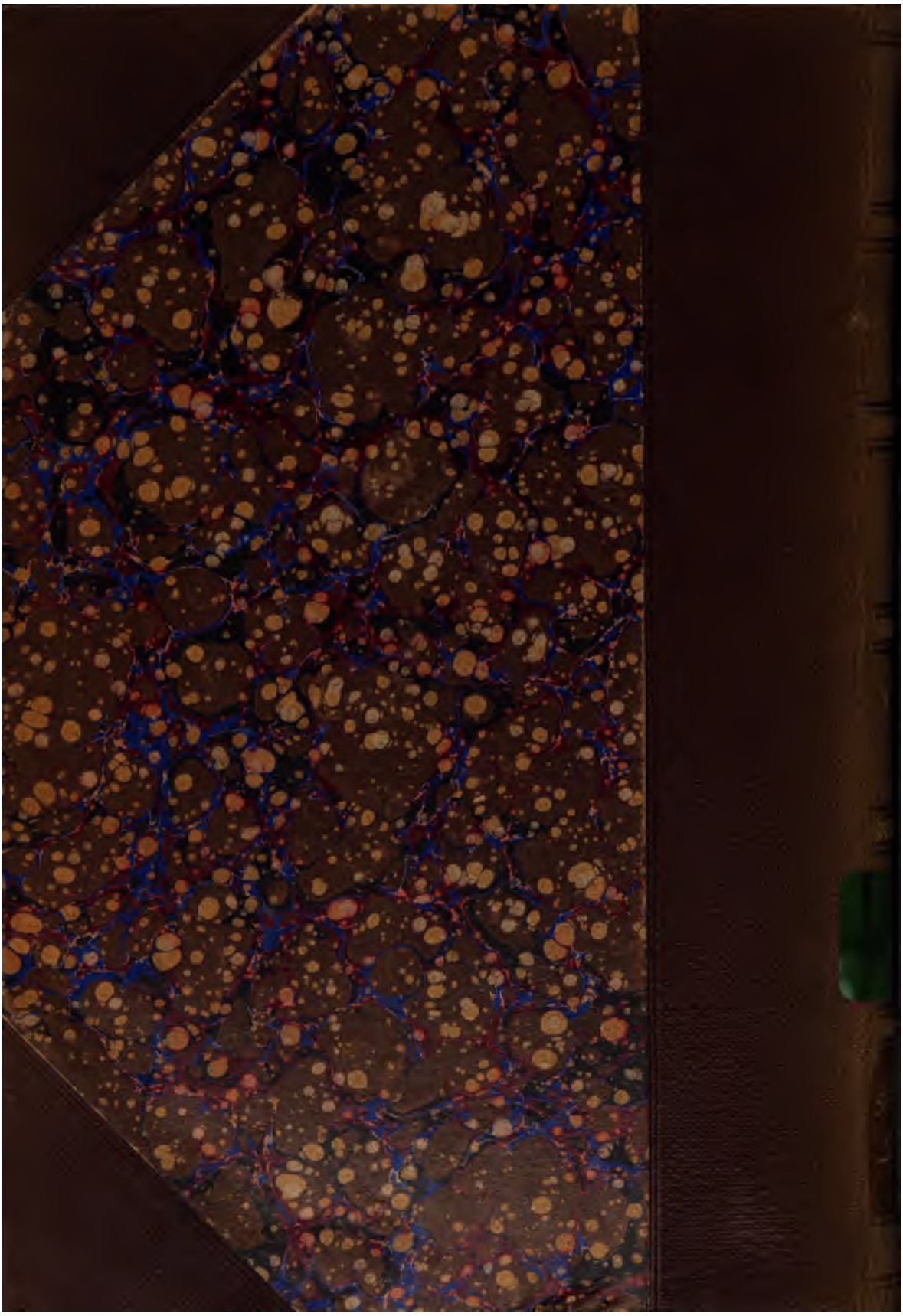
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